Explorigins 2022 Colloquium

Feb. 17th

Poster session

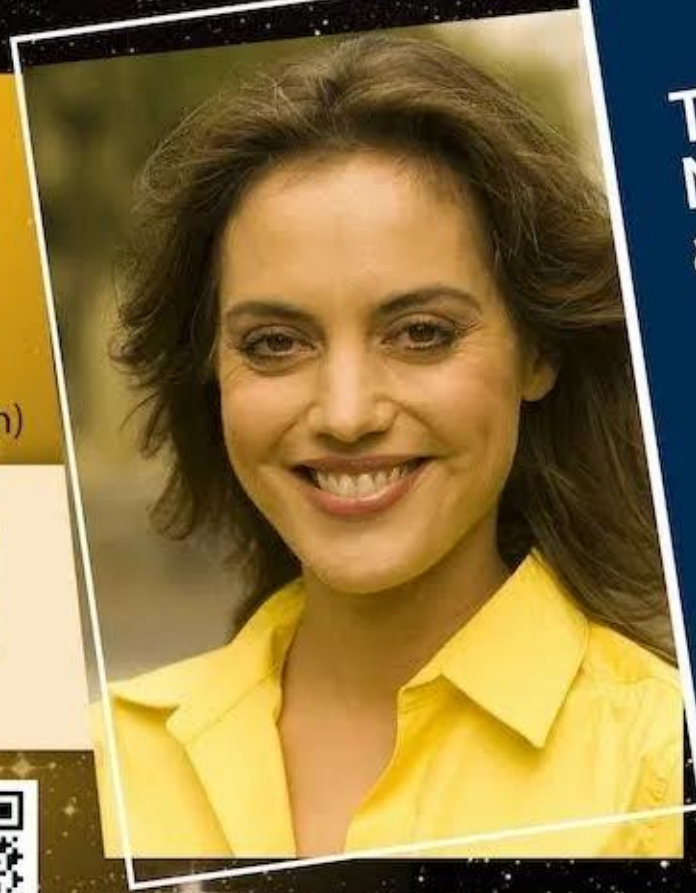
5 - 6 p.m. EST
MoSE 3rd & 4th fl. atriums

Feb. 18th

Oral Session

10 a.m. - 3:45 p.m. EST
BlueJeans (virtual) and
Suddath Rm, IBB (GA Tech)

Come hear from early carreer individuals who explore, conceptualize, celebrate, and discover pieces of space, life's origins, and astrobiology



Keynote:

Dr. **Amy Mainzer**
U. Arizona

Talk: "Don't Look Up: Near-Earth Asteroids and Comets"

Feb. 18th, virtual, 1-2 p.m. EST

- PI of NASA's Near-Earth Wide-Field Infrared Survey Explorer (NEOWISE)
- Lead of NASA's Near-Earth Object (NEO) Surveyor
- Netflix's *Don't Look Up* Science Consultant
- PBS's *Ready Jet Go!* host and executive producer

<<< Register

Schedule and more info >>>

Georgia Tech Astrobiology | C-STAR

1
00:00:07,990 --> 00:00:05,430
thank you everyone so much for waiting

2
00:00:10,629 --> 00:00:08,000
and i'm becca and i am thrilled to

3
00:00:12,390 --> 00:00:10,639
introduce our keynote speaker for today

4
00:00:13,270 --> 00:00:12,400
dr amy mainzer

5
00:00:17,990 --> 00:00:13,280
so

6
00:00:20,230 --> 00:00:18,000
planetary science at the university of

7
00:00:22,390 --> 00:00:20,240
arizona before that she was a senior

8
00:00:24,230 --> 00:00:22,400
research scientist at nasa's jet

9
00:00:26,550 --> 00:00:24,240
propulsion laboratory

10
00:00:28,470 --> 00:00:26,560
her research interests include asteroids

11
00:00:31,029 --> 00:00:28,480
and comets particularly those that

12
00:00:33,350 --> 00:00:31,039
approach the earth instrumentation for

13
00:00:35,430 --> 00:00:33,360

remote sensing and applications of

14
00:00:38,389 --> 00:00:35,440
remote sensing for monitoring invasive

15
00:00:40,950 --> 00:00:38,399
species on earth

16
00:00:43,910 --> 00:00:40,960
professor mainz mainzer is the principal

17
00:00:46,470 --> 00:00:43,920
investigator of nasa's near earth object

18
00:00:48,790 --> 00:00:46,480
wide field infrared survey explorer or

19
00:00:51,110 --> 00:00:48,800
neowise mission

20
00:00:52,549 --> 00:00:51,120
an earth orbiting space telescope that

21
00:00:54,150 --> 00:00:52,559
is searching for earth approaching

22
00:00:55,990 --> 00:00:54,160
asteroids and comets

23
00:00:59,430 --> 00:00:56,000
she is also the lead of nasa's

24
00:01:01,270 --> 00:00:59,440
near-earth object neo surveyor mission

25
00:01:02,709 --> 00:01:01,280
which will carry out a comprehensive

26
00:01:04,869 --> 00:01:02,719
survey of

27
00:01:07,590 --> 00:01:04,879
asteroids and comets using a dedicated

28
00:01:10,310 --> 00:01:07,600
space telescope the neo surveyor mission

29
00:01:12,630 --> 00:01:10,320
has entered its preliminary design phase

30
00:01:14,230 --> 00:01:12,640
and is scheduled for launch in march of

31
00:01:15,749 --> 00:01:14,240
2026

32
00:01:18,469 --> 00:01:15,759
prior to joining

33
00:01:21,030 --> 00:01:18,479
the jet propulsion laboratory in 2003

34
00:01:22,870 --> 00:01:21,040
she designed and built the fine guidance

35
00:01:24,070 --> 00:01:22,880
sensor for nasa's spitzer space

36
00:01:26,630 --> 00:01:24,080
telescope

37
00:01:29,030 --> 00:01:26,640
as an engineer at lockheed martin

38
00:01:31,109 --> 00:01:29,040

the sensor she built was used daily by

39
00:01:33,429 --> 00:01:31,119
the observatory to initialize its

40
00:01:37,910 --> 00:01:33,439
pointing system throughout its mission

41
00:01:40,710 --> 00:01:37,920
from 2003 until its end in 2019.

42
00:01:43,990 --> 00:01:40,720
professor mainzer serves as the science

43
00:01:46,789 --> 00:01:44,000
curriculum consultant on camera host and

44
00:01:49,990 --> 00:01:46,799
executive producer of the pbs kids

45
00:01:52,230 --> 00:01:50,000
series ready jet go a tv show aimed at

46
00:01:54,870 --> 00:01:52,240
teaching physical science and earth

47
00:01:57,030 --> 00:01:54,880
science to kids ages three to eight

48
00:01:58,389 --> 00:01:57,040
and she served as a science consultant

49
00:02:00,550 --> 00:01:58,399
for the netflix

50
00:02:02,709 --> 00:02:00,560
movie don't look up

51
00:02:05,109 --> 00:02:02,719
professor mainzer is the past chair of

52
00:02:07,749 --> 00:02:05,119
the american astronomical societies

53
00:02:09,990 --> 00:02:07,759
division for planetary sciences the

54
00:02:12,229 --> 00:02:10,000
world's largest professional society of

55
00:02:14,309 --> 00:02:12,239
planetary scientists

56
00:02:17,110 --> 00:02:14,319
she serves as the chair of nasa's

57
00:02:19,190 --> 00:02:17,120
planetary science advisory committee and

58
00:02:20,949 --> 00:02:19,200
is a member of the nasa advisory council

59
00:02:23,350 --> 00:02:20,959
science committee

60
00:02:24,790 --> 00:02:23,360
so without further ado take it away dr

61
00:02:27,430 --> 00:02:24,800
mainzer

62
00:02:29,110 --> 00:02:27,440
hey thanks so much uh so

63
00:02:31,030 --> 00:02:29,120

i really appreciate the opportunity to

64
00:02:33,350 --> 00:02:31,040
talk with everybody here today i thought

65
00:02:35,030 --> 00:02:33,360
what i would do is is kind of present a

66
00:02:37,350 --> 00:02:35,040
broad overview of

67
00:02:38,869 --> 00:02:37,360
why asteroids and comets are important

68
00:02:39,910 --> 00:02:38,879
to the study of the origin of life or

69
00:02:42,470 --> 00:02:39,920
just you know what are some of the

70
00:02:43,750 --> 00:02:42,480
connections between these two topics

71
00:02:45,430 --> 00:02:43,760
and i think you know why it's so

72
00:02:47,190 --> 00:02:45,440
important for for people who study

73
00:02:49,270 --> 00:02:47,200
asteroids and comets similarly to work

74
00:02:51,509 --> 00:02:49,280
with folks who who study the origins of

75
00:02:52,949 --> 00:02:51,519
life because we have a lot in common and

76
00:02:55,910 --> 00:02:52,959
there's a lot of mutual connections

77
00:02:57,910 --> 00:02:55,920
between these between these topics

78
00:02:59,750 --> 00:02:57,920
and of course

79
00:03:01,270 --> 00:02:59,760
anytime you have cross-disciplinary work

80
00:03:03,030 --> 00:03:01,280
like this i think it really improves on

81
00:03:05,670 --> 00:03:03,040
both fields

82
00:03:07,670 --> 00:03:05,680
uh let's go ahead and jump right in

83
00:03:09,270 --> 00:03:07,680
and i think uh becca you'll feel free to

84
00:03:10,710 --> 00:03:09,280
stop me if we've got questions or

85
00:03:12,149 --> 00:03:10,720
anything like that it would be really

86
00:03:14,869 --> 00:03:12,159
great to get them and i'm happy to

87
00:03:17,030 --> 00:03:14,879
answer questions anytime

88
00:03:18,470 --> 00:03:17,040

i've got a lot of slides here but i kind

89
00:03:19,990 --> 00:03:18,480
of wanted to do this as sort of a broad

90
00:03:21,430 --> 00:03:20,000
overview not just of the stuff i'm

91
00:03:23,190 --> 00:03:21,440
personally working on with you know with

92
00:03:24,869 --> 00:03:23,200
my group but also just you know some of

93
00:03:26,789 --> 00:03:24,879
the things that are really fascinating

94
00:03:28,149 --> 00:03:26,799
to me in the field that i hope i hope

95
00:03:29,670 --> 00:03:28,159
you'll like too

96
00:03:31,430 --> 00:03:29,680
so uh one of the things about the solar

97
00:03:33,670 --> 00:03:31,440
system it's just an incredibly busy

98
00:03:35,509 --> 00:03:33,680
place uh i hope everybody can see this

99
00:03:38,229 --> 00:03:35,519
but uh the green dots here these are the

100
00:03:39,670 --> 00:03:38,239
main belt asteroids so this is where the

101
00:03:41,910 --> 00:03:39,680
bulk of the asteroids in the inner solar

102
00:03:43,589 --> 00:03:41,920
system are between mars and jupiter

103
00:03:44,869 --> 00:03:43,599
and we know close to a million of these

104
00:03:47,750 --> 00:03:44,879
objects now

105
00:03:49,910 --> 00:03:47,760
as of today most of these objects stay

106
00:03:51,270 --> 00:03:49,920
in very stable orbits

107
00:03:52,789 --> 00:03:51,280
they just they just keep going around

108
00:03:53,750 --> 00:03:52,799
around around the sun for billions of

109
00:03:55,750 --> 00:03:53,760
years

110
00:03:57,910 --> 00:03:55,760
they don't really change their orbits

111
00:04:00,149 --> 00:03:57,920
terribly much for most of them but

112
00:04:01,509 --> 00:04:00,159
sometimes there are exceptions to this

113
00:04:03,110 --> 00:04:01,519

you'll notice there's a couple of other

114
00:04:05,429 --> 00:04:03,120
interesting structures here there's a

115
00:04:07,110 --> 00:04:05,439
sort of a blob of these blue objects

116
00:04:08,390 --> 00:04:07,120
over here and another one over here it's

117
00:04:10,550 --> 00:04:08,400
a little hard to see on the screen but

118
00:04:12,309 --> 00:04:10,560
that is the planet jupiter so these are

119
00:04:13,670 --> 00:04:12,319
asteroids that are gravitationally bound

120
00:04:15,429 --> 00:04:13,680
to jupiter

121
00:04:17,430 --> 00:04:15,439
and their orbits are sculpted by

122
00:04:19,509 --> 00:04:17,440
jupiter's powerful gravity

123
00:04:22,150 --> 00:04:19,519
you can also see a population of reddish

124
00:04:23,590 --> 00:04:22,160
objects in the interior orbits here

125
00:04:25,670 --> 00:04:23,600
these are what we call near-earth

126
00:04:27,590 --> 00:04:25,680
objects and we know of about close to 30

127
00:04:29,270 --> 00:04:27,600
000 of those but we believe that this is

128
00:04:31,510 --> 00:04:29,280
only the tip of the iceberg in terms of

129
00:04:33,749 --> 00:04:31,520
the total population of such objects and

130
00:04:35,189 --> 00:04:33,759
these are the ones we pay attention to

131
00:04:37,749 --> 00:04:35,199
from the perspective of looking for

132
00:04:39,189 --> 00:04:37,759
potential impactors on the earth

133
00:04:41,350 --> 00:04:39,199
so what i'm going to talk about today is

134
00:04:42,710 --> 00:04:41,360
just sort of how do these things move

135
00:04:44,150 --> 00:04:42,720
around through the solar system what are

136
00:04:47,030 --> 00:04:44,160
their characteristics and how can they

137
00:04:49,030 --> 00:04:47,040
have an influence on the origin of life

138
00:04:51,189 --> 00:04:49,040

so let's uh let's get started with that

139
00:04:52,790 --> 00:04:51,199
so first if you want to make asteroids

140
00:04:54,710 --> 00:04:52,800
and comets you first have to make a

141
00:04:56,310 --> 00:04:54,720
solar system and to do that you

142
00:04:57,990 --> 00:04:56,320
basically have a huge cloud of gas and

143
00:05:00,710 --> 00:04:58,000
dust that collapses under the influence

144
00:05:02,790 --> 00:05:00,720
of gravity and then is acted upon by gas

145
00:05:04,550 --> 00:05:02,800
pressure and and rotation of the effects

146
00:05:07,029 --> 00:05:04,560
of angular momentum

147
00:05:10,390 --> 00:05:07,039
so what you have is uh i i just really

148
00:05:11,909 --> 00:05:10,400
love this uh this particular simulation

149
00:05:14,310 --> 00:05:11,919
because it really lets you see very

150
00:05:16,390 --> 00:05:14,320
clearly just exactly how how quickly

151
00:05:17,350 --> 00:05:16,400
things progress this is time in years up

152
00:05:19,110 --> 00:05:17,360
here

153
00:05:21,110 --> 00:05:19,120
and so you can see very quickly we start

154
00:05:23,590 --> 00:05:21,120
to form condensations out of the

155
00:05:25,749 --> 00:05:23,600
pre-solar nebula and the beginnings of

156
00:05:27,350 --> 00:05:25,759
stars uh starting to kick off here and

157
00:05:30,310 --> 00:05:27,360
then once the process of star formation

158
00:05:32,950 --> 00:05:30,320
gets going it's it proceeds very rapidly

159
00:05:34,629 --> 00:05:32,960
with lots of things being spat out a lot

160
00:05:35,990 --> 00:05:34,639
of objects and different masses and each

161
00:05:38,710 --> 00:05:36,000
one of these is a solar system

162
00:05:40,150 --> 00:05:38,720
presumably so if we zoom in now on

163
00:05:42,230 --> 00:05:40,160

what's happening

164
00:05:44,070 --> 00:05:42,240
with each of these little individual

165
00:05:46,469 --> 00:05:44,080
objects that are being born out of this

166
00:05:48,469 --> 00:05:46,479
out of this pre-solar nebula but now we

167
00:05:50,150 --> 00:05:48,479
can really get a sense for how we get

168
00:05:51,909 --> 00:05:50,160
solar systems so if we just i'm going to

169
00:05:52,870 --> 00:05:51,919
kind of step us forward here on this

170
00:05:54,710 --> 00:05:52,880
movie

171
00:05:57,110 --> 00:05:54,720
but basically now we're zooming in on

172
00:05:59,350 --> 00:05:57,120
each one of those little stars that uh

173
00:06:01,990 --> 00:05:59,360
that formed out of the out of the cloud

174
00:06:04,629 --> 00:06:02,000
there and you can start to see a disk of

175
00:06:06,870 --> 00:06:04,639
material forming around each one

176
00:06:09,029 --> 00:06:06,880
and it's uh again being acted up upon by

177
00:06:11,510 --> 00:06:09,039
the the joint influences of gravity and

178
00:06:13,350 --> 00:06:11,520
angular momentum and gas pressure

179
00:06:16,870 --> 00:06:13,360
but basically you very quickly start to

180
00:06:18,629 --> 00:06:16,880
condense um instabilities in the disk

181
00:06:20,469 --> 00:06:18,639
and you have local regions where the

182
00:06:22,390 --> 00:06:20,479
gravity is a bit stronger the material

183
00:06:24,390 --> 00:06:22,400
starts to accumulate and not only do you

184
00:06:27,189 --> 00:06:24,400
get stars but you you very quickly start

185
00:06:29,909 --> 00:06:27,199
to produce the seeds of planets as well

186
00:06:32,469 --> 00:06:29,919
as uh some of the planetesimals that

187
00:06:35,270 --> 00:06:32,479
don't quite make it interplanetary to

188
00:06:37,029 --> 00:06:35,280

full planet and planetary mass objects

189
00:06:38,469 --> 00:06:37,039
uh so basically moving right along here

190
00:06:40,070 --> 00:06:38,479
you can quickly see we get all kinds of

191
00:06:41,749 --> 00:06:40,080
varieties of different solar system

192
00:06:42,790 --> 00:06:41,759
discs forming out of the out of the

193
00:06:44,309 --> 00:06:42,800
material

194
00:06:47,110 --> 00:06:44,319
uh leading to all kinds of different

195
00:06:48,710 --> 00:06:47,120
planetary systems now in our case um we

196
00:06:51,430 --> 00:06:48,720
have an asteroid belt and a bunch of

197
00:06:53,510 --> 00:06:51,440
small bodies that are leftovers that

198
00:06:55,029 --> 00:06:53,520
didn't quite get swept up into planets

199
00:06:56,710 --> 00:06:55,039
and and that's in a nutshell how you get

200
00:06:58,309 --> 00:06:56,720
asteroids most of the material goes into

201
00:07:00,469 --> 00:06:58,319
planets in the in the central star or

202
00:07:02,469 --> 00:07:00,479
stars in the solar system but a lot of

203
00:07:04,790 --> 00:07:02,479
it gets left behind and and that which

204
00:07:06,710 --> 00:07:04,800
does not get swept up uh eventually goes

205
00:07:07,909 --> 00:07:06,720
into what we know today as asteroids and

206
00:07:09,830 --> 00:07:07,919
comets

207
00:07:11,749 --> 00:07:09,840
so uh so you can see the discs really

208
00:07:13,670 --> 00:07:11,759
starting to form here you can see gaps

209
00:07:15,029 --> 00:07:13,680
as planets are created and start to

210
00:07:16,950 --> 00:07:15,039
clear out material but not everything

211
00:07:17,830 --> 00:07:16,960
makes it into a planet is the upshot of

212
00:07:23,909 --> 00:07:17,840
this

213
00:07:25,990 --> 00:07:23,919

taken with the atacama large millimeter

214
00:07:27,510 --> 00:07:26,000
and some millimeter array or alma

215
00:07:29,029 --> 00:07:27,520
uh these are pictures of real solar

216
00:07:31,270 --> 00:07:29,039
systems so through our previous slide we

217
00:07:32,950 --> 00:07:31,280
had this we had the simulations and here

218
00:07:34,550 --> 00:07:32,960
we have the actual data

219
00:07:36,150 --> 00:07:34,560
so these are actual solar systems in the

220
00:07:37,909 --> 00:07:36,160
process of forming their own planets and

221
00:07:39,670 --> 00:07:37,919
their own asteroid belts

222
00:07:41,270 --> 00:07:39,680
and you can see here the gaps being

223
00:07:43,270 --> 00:07:41,280
cleared out as the planets sweep up

224
00:07:45,670 --> 00:07:43,280
material but there's a lot of stuff left

225
00:07:48,390 --> 00:07:45,680
over so presumably each of these solar

226
00:07:50,710 --> 00:07:48,400
systems have their own asteroid belts

227
00:07:52,950 --> 00:07:50,720
and swarms of comets and so forth

228
00:07:54,469 --> 00:07:52,960
so uh if we zoom in on one of these in

229
00:07:57,029 --> 00:07:54,479
particular here you can get a sense of

230
00:07:58,629 --> 00:07:57,039
the scale this is a an object here

231
00:08:00,710 --> 00:07:58,639
called hl tau

232
00:08:02,230 --> 00:08:00,720
and these are millimeter images of it

233
00:08:03,990 --> 00:08:02,240
and you can see this is an area about

234
00:08:05,749 --> 00:08:04,000
the size of the orbit of neptune so just

235
00:08:08,070 --> 00:08:05,759
to get a sense of scale for just exactly

236
00:08:09,110 --> 00:08:08,080
how big these these debris systems can

237
00:08:11,110 --> 00:08:09,120
be

238
00:08:13,589 --> 00:08:11,120

and you can see where where our solar

239
00:08:15,430 --> 00:08:13,599
system would fit in comparison

240
00:08:17,749 --> 00:08:15,440
so in any event this is more or less how

241
00:08:19,990 --> 00:08:17,759
you start to get asteroids uh here's

242
00:08:22,150 --> 00:08:20,000
another fabulous image that i think

243
00:08:24,550 --> 00:08:22,160
really illustrates the point this is a

244
00:08:26,629 --> 00:08:24,560
little tiny piece of a comet and uh

245
00:08:27,990 --> 00:08:26,639
zooming in here this is a an image from

246
00:08:29,909 --> 00:08:28,000
uh hope ishii at the university of

247
00:08:31,589 --> 00:08:29,919
hawaii uh and if you if you zoom in you

248
00:08:33,269 --> 00:08:31,599
can really start to see this is these

249
00:08:34,870 --> 00:08:33,279
are the aggregates of all of these

250
00:08:37,909 --> 00:08:34,880
little particles of dust that have

251
00:08:39,350 --> 00:08:37,919
accumulated uh over time and eventually

252
00:08:40,949 --> 00:08:39,360
these things grow and this is what

253
00:08:42,550 --> 00:08:40,959
becomes the asteroids and the comets

254
00:08:44,230 --> 00:08:42,560
that we have left over today from the

255
00:08:46,710 --> 00:08:44,240
formation event

256
00:08:48,389 --> 00:08:46,720
okay so now talking specifically about

257
00:08:50,470 --> 00:08:48,399
the the near earth objects why do i keep

258
00:08:52,470 --> 00:08:50,480
saying object instead of just asteroid

259
00:08:54,790 --> 00:08:52,480
well in this case i mean two classes of

260
00:08:56,230 --> 00:08:54,800
objects i'm referring to both asteroids

261
00:08:58,230 --> 00:08:56,240
and comets

262
00:08:59,990 --> 00:08:58,240
when we talk about asteroids

263
00:09:01,829 --> 00:09:00,000

people typically think of rocky objects

264
00:09:04,070 --> 00:09:01,839
things that are primarily composed of

265
00:09:05,829 --> 00:09:04,080
rocky and refractory materials

266
00:09:08,710 --> 00:09:05,839
on the other hand we have comets which

267
00:09:11,030 --> 00:09:08,720
contain a lot more ices mixed together

268
00:09:12,870 --> 00:09:11,040
and all all held together in a rocky

269
00:09:15,670 --> 00:09:12,880
matrix i like to think of them now as

270
00:09:17,670 --> 00:09:15,680
kind of opposite sides of a spectrum

271
00:09:19,590 --> 00:09:17,680
today we know that asteroids span the

272
00:09:22,550 --> 00:09:19,600
gamut of everything from from really

273
00:09:24,949 --> 00:09:22,560
nearly solid pieces of nickel and iron

274
00:09:26,949 --> 00:09:24,959
do things that are very weak assemblages

275
00:09:29,110 --> 00:09:26,959
of rocky materials mixed together with

276
00:09:30,630 --> 00:09:29,120
isis that are very much like comets uh

277
00:09:32,310 --> 00:09:30,640
they can sometimes in some cases we

278
00:09:33,910 --> 00:09:32,320
think the comets that have just gotten

279
00:09:36,230 --> 00:09:33,920
too close to their central star and have

280
00:09:37,829 --> 00:09:36,240
lost a lot of their icy material on the

281
00:09:40,389 --> 00:09:37,839
other hand you have the comets which are

282
00:09:42,790 --> 00:09:40,399
mostly mixtures of ices and rocks held

283
00:09:44,630 --> 00:09:42,800
held weakly together so these things

284
00:09:46,230 --> 00:09:44,640
span the gamut sometimes we see objects

285
00:09:47,750 --> 00:09:46,240
that look like from their orbits they

286
00:09:50,310 --> 00:09:47,760
have perfectly normal main belt

287
00:09:52,470 --> 00:09:50,320
asteroids nearly circular orbits and yet

288
00:09:54,550 --> 00:09:52,480

sometimes they sprout tails just like a

289
00:09:55,990 --> 00:09:54,560
comet does and on the flip side like i

290
00:09:57,430 --> 00:09:56,000
mentioned sometimes we see asteroids

291
00:09:59,590 --> 00:09:57,440
where it looks like this thing used to

292
00:10:01,350 --> 00:09:59,600
be a comet and it's just made one too

293
00:10:03,269 --> 00:10:01,360
many passes by the sun

294
00:10:04,949 --> 00:10:03,279
but in general that's uh that's why we

295
00:10:06,949 --> 00:10:04,959
say near earth objects because we refer

296
00:10:08,710 --> 00:10:06,959
to both classes of types of things

297
00:10:11,269 --> 00:10:08,720
asteroids and comets

298
00:10:13,190 --> 00:10:11,279
uh now the classification of something

299
00:10:14,710 --> 00:10:13,200
as a near-earth object

300
00:10:16,550 --> 00:10:14,720
has to do with its per helium the

301
00:10:18,870 --> 00:10:16,560
closest approach point to the sun in its

302
00:10:20,790 --> 00:10:18,880
orbit to be classified as a neutral

303
00:10:22,949 --> 00:10:20,800
object it has to get within 1.3

304
00:10:24,790 --> 00:10:22,959
astronomical units of the sun that means

305
00:10:25,910 --> 00:10:24,800
1.3 times the distance between the earth

306
00:10:27,829 --> 00:10:25,920
and the sun

307
00:10:29,110 --> 00:10:27,839
and that's just how we how we classify

308
00:10:30,710 --> 00:10:29,120
these objects

309
00:10:32,230 --> 00:10:30,720
okay so from a from an origins

310
00:10:34,310 --> 00:10:32,240
perspective why would we care about

311
00:10:35,829 --> 00:10:34,320
these well of course they can impact the

312
00:10:37,910 --> 00:10:35,839
earth and and that can have major

313
00:10:40,310 --> 00:10:37,920

consequences for life both both good and

314
00:10:41,829 --> 00:10:40,320
bad uh these are sources of volatile

315
00:10:43,190 --> 00:10:41,839
rich material that can be delivered to

316
00:10:45,110 --> 00:10:43,200
the earth there's been a lot of

317
00:10:46,550 --> 00:10:45,120
discussion about exactly what how much

318
00:10:48,630 --> 00:10:46,560
influence that had on the on the

319
00:10:50,470 --> 00:10:48,640
accumulation of water on the early earth

320
00:10:52,470 --> 00:10:50,480
and of course obviously these objects

321
00:10:54,550 --> 00:10:52,480
can cause tremendous disruptions uh to

322
00:10:55,990 --> 00:10:54,560
our biosphere and and

323
00:10:56,790 --> 00:10:56,000
we'll see evidence of that here coming

324
00:10:58,870 --> 00:10:56,800
up

325
00:11:01,110 --> 00:10:58,880
okay so so i have posed here four

326
00:11:02,550 --> 00:11:01,120
questions about small bodies and we'll

327
00:11:03,509 --> 00:11:02,560
try and step through each one of these

328
00:11:05,269 --> 00:11:03,519
here

329
00:11:06,389 --> 00:11:05,279
to just from my perspective these are

330
00:11:08,630 --> 00:11:06,399
questions that i that i think are

331
00:11:11,190 --> 00:11:08,640
interesting for one thing

332
00:11:13,670 --> 00:11:11,200
we would like to know uh when impacts

333
00:11:15,430 --> 00:11:13,680
occur and in fact specifically we'd like

334
00:11:16,790 --> 00:11:15,440
to know not just on a geological time

335
00:11:18,069 --> 00:11:16,800
scale but we'd really like to know what

336
00:11:19,910 --> 00:11:18,079
happens on what i would call a kind of a

337
00:11:21,829 --> 00:11:19,920
human time scale in other words the next

338
00:11:23,509 --> 00:11:21,839

century or so we'd like to know what

339
00:11:25,590 --> 00:11:23,519
will happen in our next century will

340
00:11:27,030 --> 00:11:25,600
there be a major impact and if so how

341
00:11:28,470 --> 00:11:27,040
bad might it be

342
00:11:30,870 --> 00:11:28,480
so we could answer both of these

343
00:11:33,430 --> 00:11:30,880
questions by finding the objects

344
00:11:34,630 --> 00:11:33,440
tracking their orbits uh and then also

345
00:11:36,630 --> 00:11:34,640
being able to say something about the

346
00:11:39,430 --> 00:11:36,640
severity of impact which basically boils

347
00:11:41,350 --> 00:11:39,440
down to constraining the kinetic energy

348
00:11:43,990 --> 00:11:41,360
and that in turn really just boils down

349
00:11:46,550 --> 00:11:44,000
to the impact energy which is the mass

350
00:11:47,990 --> 00:11:46,560
times the velocity squared

351
00:11:49,670 --> 00:11:48,000
we get the velocity once we know the

352
00:11:51,269 --> 00:11:49,680
orbit of the object so now the problem

353
00:11:52,870 --> 00:11:51,279
is how do we get a good estimate of its

354
00:11:55,430 --> 00:11:52,880
mass well that boils down to

355
00:11:57,190 --> 00:11:55,440
constraining density but the diameter is

356
00:11:59,110 --> 00:11:57,200
really the key parameter because the

357
00:12:01,670 --> 00:11:59,120
mass scales is the diameter cubed so in

358
00:12:03,190 --> 00:12:01,680
other words small uh small errors and

359
00:12:04,629 --> 00:12:03,200
measuring the size of the object can

360
00:12:06,230 --> 00:12:04,639
have a really big effect on the

361
00:12:07,670 --> 00:12:06,240
potential impact energy so we'd really

362
00:12:08,870 --> 00:12:07,680
like to know the size

363
00:12:10,550 --> 00:12:08,880

then we have a whole host of other

364
00:12:12,550 --> 00:12:10,560
parameters we'd like to understand such

365
00:12:14,389 --> 00:12:12,560
as the density the porosity object's

366
00:12:16,790 --> 00:12:14,399
shape spin state and multiplicity if it

367
00:12:20,069 --> 00:12:16,800
has binary if it has any

368
00:12:20,790 --> 00:12:20,079
binary or other moons that are orbiting

369
00:12:22,069 --> 00:12:20,800
it

370
00:12:24,710 --> 00:12:22,079
so these are some of the questions we'd

371
00:12:26,550 --> 00:12:24,720
like to know when and how bad

372
00:12:28,069 --> 00:12:26,560
and then from an origins perspective

373
00:12:30,150 --> 00:12:28,079
we'd also like to understand just you

374
00:12:32,710 --> 00:12:30,160
know how much of this primitive

375
00:12:34,870 --> 00:12:32,720
unprocessed or very minimally processed

376
00:12:36,629 --> 00:12:34,880
material is there among the small bodies

377
00:12:38,550 --> 00:12:36,639
in the solar system and we'd also like

378
00:12:40,550 --> 00:12:38,560
to understand how this material can can

379
00:12:42,790 --> 00:12:40,560
get transported through the solar system

380
00:12:45,110 --> 00:12:42,800
and eventually arrive at the earth

381
00:12:47,829 --> 00:12:45,120
so we'll look at that as well

382
00:12:49,990 --> 00:12:47,839
uh so from the question of when now

383
00:12:51,590 --> 00:12:50,000
going back uh so we have a really

384
00:12:53,829 --> 00:12:51,600
unusual event

385
00:12:56,629 --> 00:12:53,839
in terms of uh asteroid science that

386
00:12:59,110 --> 00:12:56,639
occurred in 2013 and and this was really

387
00:13:01,110 --> 00:12:59,120
uh quite an amazing event because on

388
00:13:03,590 --> 00:13:01,120

this very day there was partic predicted

389
00:13:05,670 --> 00:13:03,600
to be a close approach of an object

390
00:13:07,430 --> 00:13:05,680
but its orbit was very very well known

391
00:13:08,629 --> 00:13:07,440
and it was not supposed to impact the

392
00:13:10,389 --> 00:13:08,639
earth at all

393
00:13:11,750 --> 00:13:10,399
so when this occurred it was a huge

394
00:13:13,750 --> 00:13:11,760
surprise

395
00:13:15,110 --> 00:13:13,760
and i remember uh hearing about this on

396
00:13:16,790 --> 00:13:15,120
the radio and thinking that this doesn't

397
00:13:18,389 --> 00:13:16,800
make any sense we knew this object was

398
00:13:20,550 --> 00:13:18,399
going to pass and it had really really

399
00:13:22,470 --> 00:13:20,560
no chance of an impact as it turned out

400
00:13:24,949 --> 00:13:22,480
this was a huge cosmic coincidence there

401
00:13:26,550 --> 00:13:24,959
really was a second asteroid

402
00:13:28,710 --> 00:13:26,560
completely out of the blue it came from

403
00:13:29,910 --> 00:13:28,720
the direction on the sky nearly uh close

404
00:13:32,150 --> 00:13:29,920
to the sun

405
00:13:34,470 --> 00:13:32,160
and it exploded over over the surface of

406
00:13:36,310 --> 00:13:34,480
the earth in russia so here are the

407
00:13:38,069 --> 00:13:36,320
contrails one of the reasons this is an

408
00:13:39,990 --> 00:13:38,079
important event is because it is so well

409
00:13:41,509 --> 00:13:40,000
studied with all the dash cams and

410
00:13:44,069 --> 00:13:41,519
security cameras and cell phones that

411
00:13:45,750 --> 00:13:44,079
people had we have a really good idea of

412
00:13:47,430 --> 00:13:45,760
what its orbital trajectory was that's

413
00:13:48,550 --> 00:13:47,440

how we know it was a completely separate

414
00:13:50,389 --> 00:13:48,560
object

415
00:13:52,870 --> 00:13:50,399
from the original one that i that i

416
00:13:55,590 --> 00:13:52,880
mentioned and uh we also were able to

417
00:13:58,310 --> 00:13:55,600
recover fragments and pieces of it

418
00:14:00,150 --> 00:13:58,320
so it it broke a lot of windows this

419
00:14:02,230 --> 00:14:00,160
object exploded high up in the earth's

420
00:14:04,069 --> 00:14:02,240
atmosphere it was not large enough to

421
00:14:05,189 --> 00:14:04,079
make it in intact all the way to the

422
00:14:07,189 --> 00:14:05,199
ground

423
00:14:08,550 --> 00:14:07,199
so that's that's really really good but

424
00:14:09,990 --> 00:14:08,560
it was able to break a lot of windows

425
00:14:12,230 --> 00:14:10,000
and it did send

426
00:14:13,990 --> 00:14:12,240
about 1600 people or so to the hospital

427
00:14:15,030 --> 00:14:14,000
from mostly from injuries from broken

428
00:14:16,870 --> 00:14:15,040
glass

429
00:14:17,990 --> 00:14:16,880
people saw the explosion in the sky and

430
00:14:19,750 --> 00:14:18,000
they went to the windows to take

431
00:14:20,710 --> 00:14:19,760
pictures of it and then the shock wave

432
00:14:23,350 --> 00:14:20,720
hit

433
00:14:25,030 --> 00:14:23,360
so uh but this uh this does sort of beg

434
00:14:27,030 --> 00:14:25,040
the question as to exactly when the next

435
00:14:28,790 --> 00:14:27,040
impact might occur on time skills that

436
00:14:32,230 --> 00:14:28,800
you know we are caring about that we

437
00:14:34,389 --> 00:14:32,240
care about is as people uh in times on

438
00:14:36,470 --> 00:14:34,399

on the scale of the next century or so

439
00:14:38,310 --> 00:14:36,480
okay so these guys uh they do make it

440
00:14:39,269 --> 00:14:38,320
out but yeah it was quite a surprise for

441
00:14:41,350 --> 00:14:39,279
everybody

442
00:14:43,110 --> 00:14:41,360
so again how often does this happen and

443
00:14:46,230 --> 00:14:43,120
what are we doing about it if anything

444
00:14:47,509 --> 00:14:46,240
um what should we be doing about it

445
00:14:50,310 --> 00:14:47,519
so uh

446
00:14:52,629 --> 00:14:50,320
this now is a one of the very best

447
00:14:54,629 --> 00:14:52,639
studied objects right here and uh this

448
00:14:57,030 --> 00:14:54,639
is of course the the famous chick salute

449
00:14:58,790 --> 00:14:57,040
impactor that hit off the gulf of mexico

450
00:15:00,230 --> 00:14:58,800
so the object that exploded over russia

451
00:15:02,069 --> 00:15:00,240
was very very tiny we think it was

452
00:15:04,790 --> 00:15:02,079
somewhere in the neighborhood of only 17

453
00:15:06,470 --> 00:15:04,800
to 20 meters across but this object was

454
00:15:08,389 --> 00:15:06,480
much larger this was an object that was

455
00:15:10,310 --> 00:15:08,399
somewhere between 5 to 10 kilometers

456
00:15:12,069 --> 00:15:10,320
across and now the impact doesn't just

457
00:15:14,550 --> 00:15:12,079
break windows of course it creates

458
00:15:16,550 --> 00:15:14,560
global global effects

459
00:15:18,150 --> 00:15:16,560
you can see here there's evidence of the

460
00:15:20,710 --> 00:15:18,160
of the ring structure of the crater that

461
00:15:22,790 --> 00:15:20,720
was left behind here this is a radar

462
00:15:24,710 --> 00:15:22,800
image from nasa

463
00:15:26,310 --> 00:15:24,720

from the space shuttle and you can see

464
00:15:28,470 --> 00:15:26,320
here just the scale of it uh this

465
00:15:30,550 --> 00:15:28,480
created about a 200 mile uh or 200

466
00:15:32,629 --> 00:15:30,560
kilometer wide crater and the signs of

467
00:15:34,470 --> 00:15:32,639
the impact are spread across the globe

468
00:15:36,069 --> 00:15:34,480
in the fossil record

469
00:15:38,550 --> 00:15:36,079
it had an enormous effect on the earth's

470
00:15:40,470 --> 00:15:38,560
biosphere uh you've got i've got a plot

471
00:15:42,629 --> 00:15:40,480
here of the number of genera so one

472
00:15:44,389 --> 00:15:42,639
level up from species going back over

473
00:15:46,629 --> 00:15:44,399
roughly half a billion years and you can

474
00:15:47,990 --> 00:15:46,639
see the diversification of life as time

475
00:15:50,150 --> 00:15:48,000
goes on

476
00:15:53,590 --> 00:15:50,160
eventually reaching the the impact event

477
00:15:55,829 --> 00:15:53,600
here so it did really have a profound

478
00:15:58,310 --> 00:15:55,839
impact on the biosphere

479
00:16:00,550 --> 00:15:58,320
resulting in mass extinctions life does

480
00:16:02,150 --> 00:16:00,560
eventually recover but it takes of order

481
00:16:03,990 --> 00:16:02,160
you know say five to ten million years

482
00:16:06,069 --> 00:16:04,000
or so for for it to come back after that

483
00:16:07,749 --> 00:16:06,079
so it really did have a profound effect

484
00:16:09,590 --> 00:16:07,759
and of course uh was we believe

485
00:16:11,350 --> 00:16:09,600
responsible for the extinction of the

486
00:16:13,189 --> 00:16:11,360
dinosaurs

487
00:16:14,629 --> 00:16:13,199
so uh the question is how often does

488
00:16:16,790 --> 00:16:14,639

this happen well we know that really

489
00:16:18,310 --> 00:16:16,800
large global impacts uh

490
00:16:20,150 --> 00:16:18,320
like the one that wiped out the

491
00:16:22,069 --> 00:16:20,160
dinosaurs really truly cannot be very

492
00:16:24,150 --> 00:16:22,079
frequent events or we would not be here

493
00:16:25,670 --> 00:16:24,160
human life probably would not be in its

494
00:16:27,509 --> 00:16:25,680
currently state if that was if that was

495
00:16:28,949 --> 00:16:27,519
a frequent occurrence so we think that

496
00:16:30,710 --> 00:16:28,959
things like this happen of roughly the

497
00:16:31,749 --> 00:16:30,720
scale every 100 no the sensible thing to

498
00:16:33,269 --> 00:16:31,759
do if we really want to answer the

499
00:16:35,509 --> 00:16:33,279
question of the next 100 years

500
00:16:36,949 --> 00:16:35,519
specifically is to go out and look but

501
00:16:38,389 --> 00:16:36,959
you can see evidence of craters here all

502
00:16:40,790 --> 00:16:38,399
across the earth uh this is a

503
00:16:43,590 --> 00:16:40,800
particularly large impactor similar to

504
00:16:45,110 --> 00:16:43,600
um to chiksulu not quite as big

505
00:16:47,030 --> 00:16:45,120
but this was an impact that probably

506
00:16:49,030 --> 00:16:47,040
occurred i think this is about 250

507
00:16:51,430 --> 00:16:49,040
million years ago ranging in size to

508
00:16:55,350 --> 00:16:51,440
about a kilometer across to another

509
00:16:57,910 --> 00:16:55,360
object that exploded over russia in 1908

510
00:17:00,470 --> 00:16:57,920
okay so another event that really caught

511
00:17:02,310 --> 00:17:00,480
the world's attention uh that these are

512
00:17:03,829 --> 00:17:02,320
impacts that can occur not just on on

513
00:17:06,069 --> 00:17:03,839

geological time scales but really on

514
00:17:08,949 --> 00:17:06,079
human time skills is the discovery of a

515
00:17:09,829 --> 00:17:08,959
comet uh in 1992 called shoemaker levy

516
00:17:11,189 --> 00:17:09,839
9.

517
00:17:13,189 --> 00:17:11,199
this was an object that was discovered

518
00:17:15,429 --> 00:17:13,199
just prior to its impact with the planet

519
00:17:18,069 --> 00:17:15,439
jupiter and jupiter sort of tore the

520
00:17:20,870 --> 00:17:18,079
object into pieces as it as it proceeded

521
00:17:22,230 --> 00:17:20,880
toward the impact in in 1994 and there

522
00:17:23,590 --> 00:17:22,240
was a lot of debate within the community

523
00:17:25,590 --> 00:17:23,600
about exactly what would happen to

524
00:17:27,590 --> 00:17:25,600
jupiter when the comet impacted on its

525
00:17:29,190 --> 00:17:27,600
surface and sure enough there's some

526
00:17:30,789 --> 00:17:29,200
some really spectacular images that were

527
00:17:33,350 --> 00:17:30,799
collected by by the hubble space

528
00:17:35,029 --> 00:17:33,360
telescope uh documenting that indeed you

529
00:17:37,190 --> 00:17:35,039
know the comet did leave detectable

530
00:17:39,270 --> 00:17:37,200
scars on the surface of jupiter

531
00:17:40,630 --> 00:17:39,280
and in fact uh these are each one of

532
00:17:42,070 --> 00:17:40,640
these is sort of roughly the size of the

533
00:17:43,590 --> 00:17:42,080
earth itself so that certainly got

534
00:17:45,830 --> 00:17:43,600
everybody's attention

535
00:17:48,230 --> 00:17:45,840
and at present nasa has been given some

536
00:17:50,150 --> 00:17:48,240
goals by congress uh so the first goal

537
00:17:52,470 --> 00:17:50,160
was was the so-called space card goal

538
00:17:54,750 --> 00:17:52,480

which was to find and track all of the

539
00:17:56,870 --> 00:17:54,760
or well not all but about 90 of the

540
00:17:58,950 --> 00:17:56,880
kilometer-sized and larger near-earth

541
00:18:00,630 --> 00:17:58,960
asteroids now i didn't say comets but

542
00:18:03,110 --> 00:18:00,640
nearest asteroids

543
00:18:04,950 --> 00:18:03,120
and that took the community about about

544
00:18:06,870 --> 00:18:04,960
10 years roughly to to complete and at

545
00:18:09,270 --> 00:18:06,880
this point we now believe the good news

546
00:18:10,870 --> 00:18:09,280
is that we've found more than 90 of all

547
00:18:12,950 --> 00:18:10,880
the kilometer and larger near-earth

548
00:18:14,950 --> 00:18:12,960
asteroids so that's the great news

549
00:18:16,630 --> 00:18:14,960
now congress has given nasa another

550
00:18:18,710 --> 00:18:16,640
objective which is to find ninety

551
00:18:19,750 --> 00:18:18,720
percent of all objects of all the earth

552
00:18:22,470 --> 00:18:19,760
objects

553
00:18:25,029 --> 00:18:22,480
larger than 140 meters across now that

554
00:18:27,350 --> 00:18:25,039
seems a bit specific why 140 meters why

555
00:18:29,430 --> 00:18:27,360
not 100 why not 200 well roughly this is

556
00:18:31,190 --> 00:18:29,440
the size where this is an object now

557
00:18:32,870 --> 00:18:31,200
that's capable of causing what we might

558
00:18:35,029 --> 00:18:32,880
call severe regional damage so in other

559
00:18:36,870 --> 00:18:35,039
words uh damage on a pretty wide scale

560
00:18:38,230 --> 00:18:36,880
that would would certainly cause uh

561
00:18:39,350 --> 00:18:38,240
global effects

562
00:18:44,230 --> 00:18:39,360
in its

563
00:18:46,630 --> 00:18:44,240

point that's what we're working on now

564
00:18:48,310 --> 00:18:46,640
as a community and uh you know we're

565
00:18:50,230 --> 00:18:48,320
making some progress but we have a lot

566
00:18:52,789 --> 00:18:50,240
more work to do there this is the

567
00:18:54,310 --> 00:18:52,799
current suite of of the uh observational

568
00:18:55,669 --> 00:18:54,320
program carried out by nasa there are a

569
00:18:56,789 --> 00:18:55,679
few other telescopes that i have not

570
00:18:58,789 --> 00:18:56,799
shown here

571
00:19:01,029 --> 00:18:58,799
but these are some of the workhorses so

572
00:19:03,990 --> 00:19:01,039
we've got the catalina sky survey here

573
00:19:07,190 --> 00:19:04,000
in arizona pan stars a few telescopes on

574
00:19:08,549 --> 00:19:07,200
hawaii in hawaii a new telescope that's

575
00:19:10,870 --> 00:19:08,559
being deployed in the southern

576
00:19:13,110 --> 00:19:10,880
hemisphere and i'll talk about neowise

577
00:19:15,270 --> 00:19:13,120
because that's the project i work on

578
00:19:17,270 --> 00:19:15,280
in space using infrared wavelengths of

579
00:19:18,789 --> 00:19:17,280
light instead of visible light unlike

580
00:19:19,590 --> 00:19:18,799
the other telescopes

581
00:19:21,110 --> 00:19:19,600
so

582
00:19:23,110 --> 00:19:21,120
this is the progress that we've made to

583
00:19:25,510 --> 00:19:23,120
date on the earth asteroid discoveries

584
00:19:28,390 --> 00:19:25,520
and if you separate these out by size

585
00:19:30,470 --> 00:19:28,400
the kilometer class near earth asteroids

586
00:19:32,870 --> 00:19:30,480
you can see here this curve is

587
00:19:34,470 --> 00:19:32,880
relatively flat which we believe at this

588
00:19:36,070 --> 00:19:34,480

point means that we really have run out

589
00:19:37,430 --> 00:19:36,080
of most of the objects to discover that

590
00:19:39,110 --> 00:19:37,440
we really have found the majority of

591
00:19:41,270 --> 00:19:39,120
these objects in this very large size

592
00:19:42,870 --> 00:19:41,280
category of asteroids but for the

593
00:19:44,150 --> 00:19:42,880
smaller objects the curves just keep

594
00:19:45,510 --> 00:19:44,160
going up and up and up meaning we

595
00:19:47,029 --> 00:19:45,520
haven't come close to exhausting the

596
00:19:49,350 --> 00:19:47,039
population yet

597
00:19:51,029 --> 00:19:49,360
and if we break them down today with the

598
00:19:52,710 --> 00:19:51,039
telescopes that we currently have right

599
00:19:54,630 --> 00:19:52,720
now most of the things we're discovering

600
00:19:56,230 --> 00:19:54,640
are on the smaller size

601
00:19:58,070 --> 00:19:56,240
end of the scale and that is because we

602
00:19:59,750 --> 00:19:58,080
are limited in what we can see we kind

603
00:20:01,590 --> 00:19:59,760
of just can't see that far away from the

604
00:20:03,350 --> 00:20:01,600
earth so we kind of have to wait for

605
00:20:04,710 --> 00:20:03,360
things to come to us and as i mentioned

606
00:20:06,470 --> 00:20:04,720
there are a lot more small pieces than

607
00:20:08,390 --> 00:20:06,480
there are really big ones so we're

608
00:20:09,669 --> 00:20:08,400
having a harder time

609
00:20:11,750 --> 00:20:09,679
achieving those really high levels of

610
00:20:13,750 --> 00:20:11,760
completeness on the larger objects and

611
00:20:15,430 --> 00:20:13,760
to do that we need more capability that

612
00:20:17,430 --> 00:20:15,440
can see further away

613
00:20:19,669 --> 00:20:17,440

so at present when we look at the goal

614
00:20:20,950 --> 00:20:19,679
that nasa has been given by congress we

615
00:20:22,710 --> 00:20:20,960
think that we found somewhere in the

616
00:20:24,710 --> 00:20:22,720
neighborhood of 30 to 40 percent of the

617
00:20:26,870 --> 00:20:24,720
objects large enough to cause that

618
00:20:28,470 --> 00:20:26,880
severe regional damage and up

619
00:20:30,710 --> 00:20:28,480
so we still have a lot more work to do

620
00:20:34,149 --> 00:20:30,720
and we have we are looking at some ways

621
00:20:35,830 --> 00:20:34,159
to expand capability uh as as mentioned

622
00:20:38,070 --> 00:20:35,840
in in the introduction i am working on a

623
00:20:40,070 --> 00:20:38,080
new project with with the team to build

624
00:20:41,350 --> 00:20:40,080
a more comprehensive survey telescope

625
00:20:43,029 --> 00:20:41,360
that will be capable of seeing things

626
00:20:44,549 --> 00:20:43,039
further away it's called the new earth

627
00:20:46,310 --> 00:20:44,559
object surveyor

628
00:20:47,590 --> 00:20:46,320
and its objectives are simply to to go

629
00:20:49,990 --> 00:20:47,600
out and fill out our knowledge of that

630
00:20:51,750 --> 00:20:50,000
population of objects that are large

631
00:20:53,590 --> 00:20:51,760
enough to cause severe regional damage

632
00:20:55,510 --> 00:20:53,600
and then hopefully hopefully help to

633
00:20:57,190 --> 00:20:55,520
provide some guidance on things like the

634
00:20:58,789 --> 00:20:57,200
sizes of the objects we'd like to really

635
00:20:59,909 --> 00:20:58,799
be able to find these objects and do a

636
00:21:02,470 --> 00:20:59,919
sort of a basic physical

637
00:21:04,149 --> 00:21:02,480
characterization of them and do it as

638
00:21:07,190 --> 00:21:04,159

quickly as possible

639
00:21:09,190 --> 00:21:07,200
okay so uh so that's uh that's the new

640
00:21:10,630 --> 00:21:09,200
earth object surveyor mission uh which

641
00:21:12,390 --> 00:21:10,640
we expect to discover hundreds of

642
00:21:14,390 --> 00:21:12,400
thousands of new nerf objects and

643
00:21:17,190 --> 00:21:14,400
millions of more distant objects in the

644
00:21:19,990 --> 00:21:17,200
solar system uh it will do so by

645
00:21:21,909 --> 00:21:20,000
operating at the earth sun l1 lagrange

646
00:21:23,430 --> 00:21:21,919
point so the idea is to be just outside

647
00:21:26,870 --> 00:21:23,440
the orbit of the moon where we can sit

648
00:21:28,390 --> 00:21:26,880
and survey these very wide swaths of sky

649
00:21:31,830 --> 00:21:28,400
and in particular we really want to look

650
00:21:33,830 --> 00:21:31,840
for asteroids that have very similar

651
00:21:35,110 --> 00:21:33,840
very earth-like orbits orbit similar to

652
00:21:37,110 --> 00:21:35,120
the earth because that allows them to

653
00:21:38,149 --> 00:21:37,120
have more chances of making a close

654
00:21:39,190 --> 00:21:38,159
approach

655
00:21:41,430 --> 00:21:39,200
i'm going to go through this a little

656
00:21:43,510 --> 00:21:41,440
quickly here but basically the idea is

657
00:21:45,270 --> 00:21:43,520
we have ground-based telescopes like the

658
00:21:47,909 --> 00:21:45,280
veracity ruben observatory that's coming

659
00:21:49,590 --> 00:21:47,919
online that will survey uh large swaths

660
00:21:52,310 --> 00:21:49,600
of the night sky and we'll be looking

661
00:21:54,549 --> 00:21:52,320
over here at these cones uh that sort of

662
00:21:56,230 --> 00:21:54,559
uh look at the the regions of the earth

663
00:21:57,669 --> 00:21:56,240

that are closer to the or

664
00:21:59,909 --> 00:21:57,679
rather regions of space that are closer

665
00:22:02,310 --> 00:21:59,919
to the sun on the sky so it'll provide

666
00:22:03,830 --> 00:22:02,320
some complementary capability uh to look

667
00:22:05,990 --> 00:22:03,840
out for all kinds of different asteroids

668
00:22:07,590 --> 00:22:06,000
including ones that have very circular

669
00:22:09,750 --> 00:22:07,600
earth-like orbits as well as ones that

670
00:22:12,630 --> 00:22:09,760
have more elliptical orbits

671
00:22:14,470 --> 00:22:12,640
okay so in any event if we get going on

672
00:22:16,710 --> 00:22:14,480
the sky as we expect

673
00:22:17,990 --> 00:22:16,720
we hopefully will reach

674
00:22:19,830 --> 00:22:18,000
with all of the surveys combined

675
00:22:21,669 --> 00:22:19,840
together uh in

676
00:22:24,070 --> 00:22:21,679
not too very long we will be able to get

677
00:22:26,070 --> 00:22:24,080
pretty close to that 90 goal given to

678
00:22:27,270 --> 00:22:26,080
nasa by congress so if we do that

679
00:22:29,270 --> 00:22:27,280
hopefully we'll have a quite

680
00:22:31,270 --> 00:22:29,280
comprehensive survey of the near-earth

681
00:22:34,149 --> 00:22:31,280
objects in our solar system

682
00:22:36,470 --> 00:22:34,159
and in the not-too-distant future

683
00:22:38,070 --> 00:22:36,480
so how do we do this well we've got to

684
00:22:40,149 --> 00:22:38,080
look for things that move and of course

685
00:22:42,310 --> 00:22:40,159
there's a lot of confusing sources out

686
00:22:44,070 --> 00:22:42,320
there in the sky including stars

687
00:22:46,390 --> 00:22:44,080
galaxies and even other more distant

688
00:22:48,789 --> 00:22:46,400

asteroids that really pose no no hazard

689
00:22:51,669 --> 00:22:48,799
whatsoever uh if we take this example

690
00:22:53,590 --> 00:22:51,679
image uh from the from the existing

691
00:22:56,950 --> 00:22:53,600
space telescope that we have which is

692
00:22:58,470 --> 00:22:56,960
neowise we can take a look at uh what we

693
00:23:00,470 --> 00:22:58,480
expect the field of view to be from the

694
00:23:02,149 --> 00:23:00,480
earth object surveyor missions so it

695
00:23:04,149 --> 00:23:02,159
will be a pretty large swath of sky

696
00:23:05,350 --> 00:23:04,159
we'll see at any one time

697
00:23:06,870 --> 00:23:05,360
there's all kinds of interesting things

698
00:23:08,390 --> 00:23:06,880
in the sky that we have to watch out for

699
00:23:10,230 --> 00:23:08,400
though there are potential sources of

700
00:23:13,110 --> 00:23:10,240
confusion like this lovely planetary

701
00:23:16,789 --> 00:23:13,120
nebula here a bunch of galaxies clusters

702
00:23:18,390 --> 00:23:16,799
of galaxies uh interstellar dust

703
00:23:20,230 --> 00:23:18,400
other artifacts from the telescope

704
00:23:21,270 --> 00:23:20,240
itself so how do we find the asteroids

705
00:23:23,909 --> 00:23:21,280
in all of this

706
00:23:25,270 --> 00:23:23,919
well in this particular set of data from

707
00:23:27,270 --> 00:23:25,280
ys

708
00:23:29,590 --> 00:23:27,280
we can start to suppress the background

709
00:23:31,669 --> 00:23:29,600
sources so basically map the things that

710
00:23:33,990 --> 00:23:31,679
don't move and mask them out or subtract

711
00:23:35,270 --> 00:23:34,000
them out and now we can just barely

712
00:23:37,110 --> 00:23:35,280
start to see

713
00:23:38,230 --> 00:23:37,120

the moving objects popping out and there

714
00:23:39,990 --> 00:23:38,240
they are

715
00:23:41,750 --> 00:23:40,000
these are mostly main belt asteroids

716
00:23:43,750 --> 00:23:41,760
however these are asteroids that are far

717
00:23:45,750 --> 00:23:43,760
away and never make really close

718
00:23:48,149 --> 00:23:45,760
approaches to the earth so we care about

719
00:23:49,830 --> 00:23:48,159
them from a scientific standpoint but

720
00:23:50,870 --> 00:23:49,840
from a hazard perspective we want to get

721
00:23:52,230 --> 00:23:50,880
rid of them we want to we want to

722
00:23:53,510 --> 00:23:52,240
eliminate them

723
00:23:55,350 --> 00:23:53,520
there are other artifacts we have to

724
00:23:57,669 --> 00:23:55,360
watch out for we can start to identify

725
00:23:59,669 --> 00:23:57,679
these ones as known objects

726
00:24:01,590 --> 00:23:59,679
but here is a particular one and you can

727
00:24:03,350 --> 00:24:01,600
see its motion is quite different on the

728
00:24:04,390 --> 00:24:03,360
sky from the more distant main belt

729
00:24:05,750 --> 00:24:04,400
asteroids

730
00:24:07,510 --> 00:24:05,760
this object is what we call a

731
00:24:09,669 --> 00:24:07,520
potentially hazardous asteroid it has

732
00:24:11,190 --> 00:24:09,679
one that means its orbit carries it uh

733
00:24:12,310 --> 00:24:11,200
quite close to the earth's orbit doesn't

734
00:24:13,750 --> 00:24:12,320
mean that there'll ever be a collision

735
00:24:15,190 --> 00:24:13,760
with this object or anything like that

736
00:24:17,669 --> 00:24:15,200
but it does mean this is an object that

737
00:24:19,110 --> 00:24:17,679
we pay much more careful attention to

738
00:24:21,350 --> 00:24:19,120

and these are the real targets of our

739
00:24:23,750 --> 00:24:21,360
search from the hazard perspective

740
00:24:25,669 --> 00:24:23,760
okay so if we are successful in our

741
00:24:27,750 --> 00:24:25,679
efforts to get the the survey telescope

742
00:24:29,990 --> 00:24:27,760
built basically once it launches it will

743
00:24:31,350 --> 00:24:30,000
very quickly go out and survey the the

744
00:24:33,029 --> 00:24:31,360
asteroid belt

745
00:24:36,230 --> 00:24:33,039
and the near object population it should

746
00:24:37,990 --> 00:24:36,240
accumulate a lot of things very quickly

747
00:24:39,590 --> 00:24:38,000
and hopefully getting us very close to

748
00:24:41,750 --> 00:24:39,600
that ninety percent goal given by

749
00:24:43,669 --> 00:24:41,760
congress to nasa

750
00:24:45,669 --> 00:24:43,679
okay so that's a little bit about the

751
00:24:47,269 --> 00:24:45,679
when question if we can find the objects

752
00:24:48,390 --> 00:24:47,279
get good orbits for them we can figure

753
00:24:50,230 --> 00:24:48,400
out when they might make close

754
00:24:53,269 --> 00:24:50,240
approaches but now the question of how

755
00:24:55,029 --> 00:24:53,279
bad an impact might be can be answered

756
00:24:56,549 --> 00:24:55,039
and to do that we need to make some some

757
00:24:57,990 --> 00:24:56,559
basic measurements like i said of the

758
00:25:00,070 --> 00:24:58,000
object's physical properties most

759
00:25:01,350 --> 00:25:00,080
important are the diameters as well as

760
00:25:03,269 --> 00:25:01,360
the densities

761
00:25:05,110 --> 00:25:03,279
so we're turning back to that object

762
00:25:07,669 --> 00:25:05,120
that exploded over russia this is the

763
00:25:09,750 --> 00:25:07,679

single largest crater if you will that

764
00:25:12,789 --> 00:25:09,760
that the object made and it's basically

765
00:25:14,070 --> 00:25:12,799
a six meter wide hole in in an icy lake

766
00:25:17,350 --> 00:25:14,080
this is the largest piece that was

767
00:25:18,630 --> 00:25:17,360
recovered right here on the flip side

768
00:25:21,430 --> 00:25:18,640
like i said this was an object that was

769
00:25:23,269 --> 00:25:21,440
relatively small about 20 meters across

770
00:25:25,350 --> 00:25:23,279
i broke a lot of windows but there was

771
00:25:27,590 --> 00:25:25,360
no big crater on the other hand if the

772
00:25:29,750 --> 00:25:27,600
object is just slightly larger at 50

773
00:25:31,990 --> 00:25:29,760
meters across now instead of a small

774
00:25:34,230 --> 00:25:32,000
hole in the ice you get a kilometer wide

775
00:25:35,590 --> 00:25:34,240
crater on the ground i actually have a

776
00:25:37,110 --> 00:25:35,600
couple of pieces of meteorites here

777
00:25:38,149 --> 00:25:37,120
which i'll hold up i hope everybody can

778
00:25:40,230 --> 00:25:38,159
see these

779
00:25:42,710 --> 00:25:40,240
but this little piece right here this is

780
00:25:44,310 --> 00:25:42,720
a piece of chelyabinsk so the uh the

781
00:25:45,350 --> 00:25:44,320
object right here this is one of the

782
00:25:48,549 --> 00:25:45,360
fragments

783
00:25:50,390 --> 00:25:48,559
and i also have a little fragment of the

784
00:25:52,149 --> 00:25:50,400
object that made the crater on the right

785
00:25:53,350 --> 00:25:52,159
so this one it's a bigger piece but i

786
00:25:55,590 --> 00:25:53,360
don't know if you can see it's it's

787
00:25:58,230 --> 00:25:55,600
really heavy and that's because its

788
00:26:00,630 --> 00:25:58,240

predominant composition is iron

789
00:26:02,310 --> 00:26:00,640
so you can see even very small changes

790
00:26:04,950 --> 00:26:02,320
in the size of the object

791
00:26:06,470 --> 00:26:04,960
uh when combined with uh with its with

792
00:26:08,149 --> 00:26:06,480
its density can make a very big

793
00:26:09,990 --> 00:26:08,159
difference in the outcome so that's why

794
00:26:11,510 --> 00:26:10,000
we'd like to measure the sizes and we'd

795
00:26:13,110 --> 00:26:11,520
like to have some way to constrain

796
00:26:14,230 --> 00:26:13,120
important properties like density as

797
00:26:17,190 --> 00:26:14,240
well

798
00:26:19,110 --> 00:26:17,200
okay so in measuring diameters we have

799
00:26:20,630 --> 00:26:19,120
several different tools in our arsenal

800
00:26:21,990 --> 00:26:20,640
that we can use

801
00:26:23,830 --> 00:26:22,000
one of the ones that we've been working

802
00:26:25,830 --> 00:26:23,840
with in my group is to use infrared

803
00:26:27,909 --> 00:26:25,840
measurements so in other words if we

804
00:26:30,789 --> 00:26:27,919
look at different uh the spectral energy

805
00:26:32,870 --> 00:26:30,799
distribution of typical asteroids so you

806
00:26:34,070 --> 00:26:32,880
can see that it consists of kind of two

807
00:26:36,070 --> 00:26:34,080
curves here

808
00:26:37,830 --> 00:26:36,080
in the visible portion of the spectrum

809
00:26:39,990 --> 00:26:37,840
you can see reflected sunlight bouncing

810
00:26:42,710 --> 00:26:40,000
off the surfaces of the object and then

811
00:26:44,870 --> 00:26:42,720
it's re-radiated as heat as the sun

812
00:26:47,190 --> 00:26:44,880
warms up the asteroid it get it gets

813
00:26:48,470 --> 00:26:47,200

re-radiated in these longer thermal

814
00:26:50,710 --> 00:26:48,480
infrared wavelengths and the four

815
00:26:54,230 --> 00:26:50,720
colorful bands here represent the four

816
00:26:56,149 --> 00:26:54,240
filters that we use on the wise mission

817
00:26:58,070 --> 00:26:56,159
i've got two different albedos here

818
00:26:59,909 --> 00:26:58,080
albedo is how much light is reflected

819
00:27:03,350 --> 00:26:59,919
off the surface of the object

820
00:27:06,390 --> 00:27:03,360
this right here is a is a more typical

821
00:27:07,510 --> 00:27:06,400
stony object at 17 reflectivity here and

822
00:27:09,350 --> 00:27:07,520
i'm holding up the little piece of

823
00:27:11,510 --> 00:27:09,360
chelubins in other words these objects

824
00:27:12,950 --> 00:27:11,520
are kind of lighter in color

825
00:27:14,710 --> 00:27:12,960
on the flip side we have objects that

826
00:27:16,789 --> 00:27:14,720
are extremely dark

827
00:27:18,789 --> 00:27:16,799
and reflect very little sunlight in

828
00:27:21,190 --> 00:27:18,799
optical wavelengths and here is a piece

829
00:27:22,549 --> 00:27:21,200
of a very primitive type of meteorite

830
00:27:24,549 --> 00:27:22,559
called allende

831
00:27:26,710 --> 00:27:24,559
you can see it's it's quite dark

832
00:27:28,389 --> 00:27:26,720
in color so so they range in in

833
00:27:29,830 --> 00:27:28,399
reflectivities quite dramatically and

834
00:27:32,389 --> 00:27:29,840
this can have a big influence on how

835
00:27:34,389 --> 00:27:32,399
detectable the objects are also uh how

836
00:27:35,510 --> 00:27:34,399
well we can measure the size so in a

837
00:27:37,590 --> 00:27:35,520
nutshell

838
00:27:40,070 --> 00:27:37,600

if we can collect thermal infrared

839
00:27:42,549 --> 00:27:40,080
measure measurements that sample how

840
00:27:44,389 --> 00:27:42,559
much heat the object is emitting

841
00:27:46,710 --> 00:27:44,399
we can if we know the distance to the

842
00:27:47,990 --> 00:27:46,720
object we can turn that into a pretty

843
00:27:49,350 --> 00:27:48,000
good measurement of the object's

844
00:27:51,350 --> 00:27:49,360
diameter

845
00:27:53,269 --> 00:27:51,360
now i kept mentioning the wise mission

846
00:27:55,590 --> 00:27:53,279
this is an earth orbiting telescope that

847
00:27:56,789 --> 00:27:55,600
was launched in late 2009

848
00:27:57,909 --> 00:27:56,799
and it was really designed to do

849
00:28:00,630 --> 00:27:57,919
something else the principal

850
00:28:02,870 --> 00:28:00,640
investigator is ned wright of ucla

851
00:28:04,710 --> 00:28:02,880
and it completed its prime mission uh

852
00:28:06,470 --> 00:28:04,720
making a map of the entire sky at these

853
00:28:08,070 --> 00:28:06,480
four infrared wavelengths that you see

854
00:28:09,190 --> 00:28:08,080
here ranging from three to twenty two

855
00:28:12,870 --> 00:28:09,200
microns

856
00:28:14,389 --> 00:28:12,880
uh it finished its mission in 2010 um

857
00:28:15,990 --> 00:28:14,399
but it turned out that even though its

858
00:28:17,430 --> 00:28:16,000
primary science objective was not to

859
00:28:19,350 --> 00:28:17,440
look at asteroids it was actually quite

860
00:28:22,630 --> 00:28:19,360
successful at doing so and we've been

861
00:28:24,549 --> 00:28:22,640
able to measure uh about 190 some small

862
00:28:26,230 --> 00:28:24,559
bodies including a couple thousand new

863
00:28:28,389 --> 00:28:26,240

earth objects with it

864
00:28:30,310 --> 00:28:28,399
it completed its prime mission in 2010

865
00:28:31,430 --> 00:28:30,320
and we thought that was the end of it

866
00:28:33,990 --> 00:28:31,440
but

867
00:28:36,230 --> 00:28:34,000
nasa asked us to switch it back on using

868
00:28:39,110 --> 00:28:36,240
its two remaining channels after the two

869
00:28:41,029 --> 00:28:39,120
longest wavelengths channels uh

870
00:28:42,549 --> 00:28:41,039
are no longer operational and so now

871
00:28:44,070 --> 00:28:42,559
today we are surveying asteroids and

872
00:28:46,149 --> 00:28:44,080
comets using these two remaining

873
00:28:48,070 --> 00:28:46,159
channels here at uh three and five

874
00:28:50,070 --> 00:28:48,080
microns

875
00:28:51,669 --> 00:28:50,080
so uh today we're continuing to measure

876
00:28:53,510 --> 00:28:51,679
asteroids and and

877
00:28:55,029 --> 00:28:53,520
even though predominantly uh we're not

878
00:28:56,870 --> 00:28:55,039
discovering that many objects anymore

879
00:28:58,630 --> 00:28:56,880
what we're really good at doing is

880
00:29:00,549 --> 00:28:58,640
measuring their sizes and that's that's

881
00:29:01,510 --> 00:29:00,559
what the focus of the investigation has

882
00:29:03,430 --> 00:29:01,520
been

883
00:29:05,350 --> 00:29:03,440
uh when we look at the sky

884
00:29:07,029 --> 00:29:05,360
another reason for for using infrared

885
00:29:09,590 --> 00:29:07,039
light to look for these objects is that

886
00:29:11,350 --> 00:29:09,600
the asteroids kind of stick out brightly

887
00:29:12,630 --> 00:29:11,360
compared to the stars

888
00:29:14,789 --> 00:29:12,640

and that gives us an advantage in

889
00:29:16,950 --> 00:29:14,799
finding objects particularly those that

890
00:29:18,870 --> 00:29:16,960
are already are made of

891
00:29:19,990 --> 00:29:18,880
less reflective material and that's

892
00:29:21,830 --> 00:29:20,000
helpful

893
00:29:23,830 --> 00:29:21,840
so even though invisible wavelengths of

894
00:29:25,669 --> 00:29:23,840
light an object might

895
00:29:27,750 --> 00:29:25,679
look like it is

896
00:29:29,110 --> 00:29:27,760
different brightnesses it could just be

897
00:29:30,870 --> 00:29:29,120
that we are sampling objects with

898
00:29:33,430 --> 00:29:30,880
different reflectivities and and

899
00:29:34,310 --> 00:29:33,440
different sizes in other words uh it

900
00:29:35,830 --> 00:29:34,320
lets us

901
00:29:37,190 --> 00:29:35,840
if we use infrared light we can tell the

902
00:29:39,269 --> 00:29:37,200
difference between an object that is

903
00:29:41,669 --> 00:29:39,279
small but highly reflective

904
00:29:43,510 --> 00:29:41,679
versus one that's much larger but has a

905
00:29:45,350 --> 00:29:43,520
very low reflectivity surface sort of

906
00:29:47,750 --> 00:29:45,360
like a piece of charcoal

907
00:29:48,789 --> 00:29:47,760
okay so uh i'm going to kind of whip

908
00:29:50,230 --> 00:29:48,799
through these i'm not going to walk

909
00:29:53,350 --> 00:29:50,240
through the equations but the point of

910
00:29:54,630 --> 00:29:53,360
this is to just simply say if we have a

911
00:29:56,470 --> 00:29:54,640
good measurement of an object's

912
00:29:58,789 --> 00:29:56,480
brightness at infrared wavelengths and

913
00:30:01,190 --> 00:29:58,799

we know the distance to the object

914
00:30:02,389 --> 00:30:01,200
then we can actually calculate

915
00:30:03,909 --> 00:30:02,399
its size

916
00:30:06,230 --> 00:30:03,919
and the way we do that is we have to

917
00:30:08,870 --> 00:30:06,240
make a measurement of its temperature

918
00:30:11,990 --> 00:30:08,880
and convert that measured infrared flux

919
00:30:14,389 --> 00:30:12,000
or the heat from the object back into a

920
00:30:16,470 --> 00:30:14,399
diameter and that is that is what we do

921
00:30:17,990 --> 00:30:16,480
with what we call thermal modeling so

922
00:30:19,430 --> 00:30:18,000
basically in this case we would make an

923
00:30:21,750 --> 00:30:19,440
assumption of the way the temperature is

924
00:30:24,310 --> 00:30:21,760
distributed around the asteroid and then

925
00:30:25,669 --> 00:30:24,320
from there we can we can back calculate

926
00:30:27,750 --> 00:30:25,679
the size

927
00:30:29,190 --> 00:30:27,760
so if we do that we can now get a pretty

928
00:30:31,350 --> 00:30:29,200
good measurement of how big the object

929
00:30:33,990 --> 00:30:31,360
is which goes back to the question of

930
00:30:36,470 --> 00:30:34,000
how severe an impact is likely to be

931
00:30:37,430 --> 00:30:36,480
we can also in some cases calculate

932
00:30:41,669 --> 00:30:37,440
uh

933
00:30:43,269 --> 00:30:41,679
the reflectivity and then helps us learn

934
00:30:44,789 --> 00:30:43,279
something about its its probable

935
00:30:46,950 --> 00:30:44,799
composition

936
00:30:48,389 --> 00:30:46,960
okay so if we're successful with getting

937
00:30:50,070 --> 00:30:48,399
good thermal infrared measurements we

938
00:30:51,990 --> 00:30:50,080

can usually constrain the diameters to

939
00:30:53,750 --> 00:30:52,000
between sort of 10 to 20 percent on

940
00:30:56,070 --> 00:30:53,760
average occasionally you can do a little

941
00:30:56,789 --> 00:30:56,080
better if you have a lot of observations

942
00:30:58,470 --> 00:30:56,799
but

943
00:31:00,230 --> 00:30:58,480
i would say with with good sampling you

944
00:31:01,990 --> 00:31:00,240
can you can typically know the diameters

945
00:31:03,350 --> 00:31:02,000
quite well on the other hand if all you

946
00:31:05,269 --> 00:31:03,360
have is a visible light measurement it's

947
00:31:07,269 --> 00:31:05,279
harder to do this in general

948
00:31:09,029 --> 00:31:07,279
simply because you have a pretty wide

949
00:31:11,669 --> 00:31:09,039
range of potential reflectivities of the

950
00:31:12,470 --> 00:31:11,679
surface that we have to account for

951
00:31:14,310 --> 00:31:12,480
okay

952
00:31:16,310 --> 00:31:14,320
and in addition the infrared light is is

953
00:31:18,070 --> 00:31:16,320
sensitive to both the highly reflective

954
00:31:19,509 --> 00:31:18,080
objects as well as the the really dark

955
00:31:21,669 --> 00:31:19,519
ones and that helps us get a very good

956
00:31:24,549 --> 00:31:21,679
census of the population to understand

957
00:31:26,789 --> 00:31:24,559
exactly how many objects are out there

958
00:31:28,789 --> 00:31:26,799
so when we do this with neowise we

959
00:31:30,070 --> 00:31:28,799
basically can make a plot of the sizes

960
00:31:31,750 --> 00:31:30,080
of the objects compared to the

961
00:31:33,590 --> 00:31:31,760
reflectivity

962
00:31:35,430 --> 00:31:33,600
and one of the things we found is that

963
00:31:37,350 --> 00:31:35,440

when we make this sample of near-earth

964
00:31:39,269 --> 00:31:37,360
asteroids that are chosen purely based

965
00:31:41,269 --> 00:31:39,279
on the how much heat they emit they're

966
00:31:43,029 --> 00:31:41,279
12 micron flux so how much light are

967
00:31:45,029 --> 00:31:43,039
they emitting

968
00:31:46,630 --> 00:31:45,039
in the thermal infrared what we see is

969
00:31:48,230 --> 00:31:46,640
that there there really isn't a huge

970
00:31:50,389 --> 00:31:48,240
change in the distribution of the ratio

971
00:31:52,549 --> 00:31:50,399
of dark to bright objects over a fairly

972
00:31:54,789 --> 00:31:52,559
broad range of sizes in other words we

973
00:31:56,070 --> 00:31:54,799
believe that there are these smaller low

974
00:31:58,789 --> 00:31:56,080
albedo objects out there in the

975
00:32:00,149 --> 00:31:58,799
population um but you you have to look

976
00:32:01,190 --> 00:32:00,159
in such a way that you can actually see

977
00:32:02,389 --> 00:32:01,200
them

978
00:32:03,830 --> 00:32:02,399
so uh

979
00:32:05,110 --> 00:32:03,840
other things that we have noticed in the

980
00:32:06,710 --> 00:32:05,120
course of doing this survey is that

981
00:32:08,070 --> 00:32:06,720
objects that are discovered using the

982
00:32:10,230 --> 00:32:08,080
infrared telescope tend to be on the

983
00:32:11,750 --> 00:32:10,240
larger size and they are predominantly

984
00:32:15,110 --> 00:32:11,760
low albedo

985
00:32:16,789 --> 00:32:15,120
portion of the population that we

986
00:32:18,389 --> 00:32:16,799
believe is out there but can be

987
00:32:20,070 --> 00:32:18,399
difficult for visible light telescopes

988
00:32:22,389 --> 00:32:20,080

to see simply because they're optically

989
00:32:24,710 --> 00:32:22,399
dark and that means they're faint

990
00:32:26,549 --> 00:32:24,720
but they are there nonetheless

991
00:32:28,789 --> 00:32:26,559
so what is the nature of this and how

992
00:32:31,110 --> 00:32:28,799
much of this of this low albedo material

993
00:32:32,710 --> 00:32:31,120
uh as i've said before this is some of

994
00:32:34,549 --> 00:32:32,720
the least processed material in the

995
00:32:36,230 --> 00:32:34,559
solar system it comes from the farther

996
00:32:37,350 --> 00:32:36,240
more distant reaches of the pre-solar

997
00:32:39,269 --> 00:32:37,360
nebula

998
00:32:40,789 --> 00:32:39,279
uh so it's it's evolved in a region

999
00:32:42,310 --> 00:32:40,799
where it's very cold

1000
00:32:44,070 --> 00:32:42,320
and it hasn't experienced a lot of

1001
00:32:45,990 --> 00:32:44,080
thermal processing over the course of

1002
00:32:47,750 --> 00:32:46,000
the solar system's evolution

1003
00:32:49,590 --> 00:32:47,760
we believe from our survey with neo-wise

1004
00:32:50,950 --> 00:32:49,600
that roughly 30 percent of the objects

1005
00:32:53,350 --> 00:32:50,960
that make it into near-earth object

1006
00:32:54,630 --> 00:32:53,360
space are made of this low albedo

1007
00:32:56,630 --> 00:32:54,640
material and of course some of that is

1008
00:32:59,430 --> 00:32:56,640
getting delivered to earth

1009
00:33:03,430 --> 00:32:59,440
so we also now have samples

1010
00:33:05,269 --> 00:33:03,440
back from one of the uh from a very well

1011
00:33:07,110 --> 00:33:05,279
studied uh primitive asteroid called

1012
00:33:08,950 --> 00:33:07,120
ryugu that was the subject of the

1013
00:33:10,710 --> 00:33:08,960

hayabusa2 mission so this was a

1014
00:33:13,110 --> 00:33:10,720
spacecraft that actually uh was launched

1015
00:33:14,950 --> 00:33:13,120
by jackson that went to this asteroid

1016
00:33:16,310 --> 00:33:14,960
collected a sample of it and has brought

1017
00:33:18,070 --> 00:33:16,320
it back to the earth

1018
00:33:20,630 --> 00:33:18,080
and you can see it here

1019
00:33:23,029 --> 00:33:20,640
it's extremely dark uh material and it

1020
00:33:25,029 --> 00:33:23,039
looks uh it looks like charcoal

1021
00:33:27,669 --> 00:33:25,039
so i've got uh like i said i've got a

1022
00:33:29,430 --> 00:33:27,679
sample of this this object here

1023
00:33:31,029 --> 00:33:29,440
this is another primitive meteorite

1024
00:33:32,230 --> 00:33:31,039
that's been found on the on the on the

1025
00:33:33,990 --> 00:33:32,240
earth

1026
00:33:36,230 --> 00:33:34,000
but yeah you can see that this is this

1027
00:33:37,909 --> 00:33:36,240
is material that is extremely dark

1028
00:33:40,630 --> 00:33:37,919
and so we believe that this is material

1029
00:33:43,029 --> 00:33:40,640
that uh that is often um

1030
00:33:45,350 --> 00:33:43,039
altered by the presence of water that

1031
00:33:47,509 --> 00:33:45,360
has been mixed throughout the material

1032
00:33:49,269 --> 00:33:47,519
and over time has produced a lot of

1033
00:33:51,190 --> 00:33:49,279
complex chemicals that uh that have

1034
00:33:52,470 --> 00:33:51,200
arisen so this this in turn could be

1035
00:33:54,630 --> 00:33:52,480
very important for

1036
00:33:56,149 --> 00:33:54,640
how life evolves on not just our planet

1037
00:33:57,830 --> 00:33:56,159
but potentially others in other solar

1038
00:34:00,149 --> 00:33:57,840

systems as well

1039
00:34:01,750 --> 00:34:00,159
so uh where is this material presently

1040
00:34:03,590 --> 00:34:01,760
distributed throughout our solar system

1041
00:34:05,110 --> 00:34:03,600
well uh we know in a broad sense how

1042
00:34:07,190 --> 00:34:05,120
this works but now let's take a look at

1043
00:34:09,190 --> 00:34:07,200
exactly how the details seem to have

1044
00:34:10,629 --> 00:34:09,200
evolved so in

1045
00:34:13,430 --> 00:34:10,639
in asteroids we have what we call

1046
00:34:15,190 --> 00:34:13,440
families of objects you have objects

1047
00:34:16,629 --> 00:34:15,200
that basically undergo catastrophic

1048
00:34:19,270 --> 00:34:16,639
disruptions they collide with other

1049
00:34:20,710 --> 00:34:19,280
asteroids and create a shower fragments

1050
00:34:22,950 --> 00:34:20,720
and that's how we get groupings of

1051
00:34:24,950 --> 00:34:22,960
asteroids that share similar orbits and

1052
00:34:26,629 --> 00:34:24,960
similar physical properties

1053
00:34:29,270 --> 00:34:26,639
we believe that they origin originated

1054
00:34:31,030 --> 00:34:29,280
from a common parent body by looking at

1055
00:34:32,710 --> 00:34:31,040
the characteristics of these families we

1056
00:34:34,230 --> 00:34:32,720
can sort of map out the distribution of

1057
00:34:36,629 --> 00:34:34,240
this carbonaceous material throughout

1058
00:34:39,109 --> 00:34:36,639
the solar system and try to understand a

1059
00:34:40,790 --> 00:34:39,119
little better how it is distributed

1060
00:34:42,550 --> 00:34:40,800
so when we do this

1061
00:34:43,909 --> 00:34:42,560
this is my colleague joe mccerro who

1062
00:34:45,589 --> 00:34:43,919
made these plots

1063
00:34:47,430 --> 00:34:45,599

we can basically look at the orbital

1064
00:34:49,750 --> 00:34:47,440
properties of asteroids so now if we

1065
00:34:51,349 --> 00:34:49,760
look throughout the main asteroid belt

1066
00:34:53,750 --> 00:34:51,359
so this is the region between mars and

1067
00:34:55,750 --> 00:34:53,760
jupiter here and if we plot this uh

1068
00:34:57,349 --> 00:34:55,760
semi-major axis of the orbit so in other

1069
00:34:59,990 --> 00:34:57,359
words how how far away do the objects

1070
00:35:01,670 --> 00:35:00,000
get from the sun compared to their

1071
00:35:03,349 --> 00:35:01,680
inclination so this is basically how

1072
00:35:04,630 --> 00:35:03,359
tilted the orbit is

1073
00:35:06,550 --> 00:35:04,640
when we look at this we can see some

1074
00:35:08,470 --> 00:35:06,560
really distinctive patterns

1075
00:35:09,750 --> 00:35:08,480
when we plot them by their geometric

1076
00:35:11,750 --> 00:35:09,760
albedo

1077
00:35:13,190 --> 00:35:11,760
so the reflectivities you can now see

1078
00:35:14,230 --> 00:35:13,200
that there are these these clusterings

1079
00:35:14,950 --> 00:35:14,240
here

1080
00:35:19,270 --> 00:35:14,960
in

1081
00:35:21,430 --> 00:35:19,280
very similar orbital elements they're

1082
00:35:23,430 --> 00:35:21,440
grouped together and they have similar

1083
00:35:25,750 --> 00:35:23,440
reflectivities of their surfaces so they

1084
00:35:27,829 --> 00:35:25,760
seem to be uh made of similar material

1085
00:35:29,430 --> 00:35:27,839
potentially we call these asteroid

1086
00:35:31,829 --> 00:35:29,440
families and we believe that these are

1087
00:35:33,750 --> 00:35:31,839
the products of catastrophic disruptions

1088
00:35:35,510 --> 00:35:33,760

so the something collides with another

1089
00:35:38,150 --> 00:35:35,520
asteroid and it creates the shower

1090
00:35:40,550 --> 00:35:38,160
fragments and they stick together

1091
00:35:42,710 --> 00:35:40,560
throughout throughout the main belt when

1092
00:35:44,470 --> 00:35:42,720
we subtract these asteroid families from

1093
00:35:46,310 --> 00:35:44,480
the background population of all the

1094
00:35:47,990 --> 00:35:46,320
asteroids that we know about in other

1095
00:35:49,670 --> 00:35:48,000
words these are the ones we believe are

1096
00:35:51,750 --> 00:35:49,680
dynamically connected together that they

1097
00:35:52,710 --> 00:35:51,760
did share a common parent a long time

1098
00:35:54,710 --> 00:35:52,720
ago

1099
00:35:56,150 --> 00:35:54,720
when we take these out we can now look

1100
00:35:57,430 --> 00:35:56,160
at the background distribution of

1101
00:35:59,270 --> 00:35:57,440
asteroids you can see that the the

1102
00:36:01,030 --> 00:35:59,280
subtraction of the asteroid families is

1103
00:36:03,589 --> 00:36:01,040
not completely perfect but there are

1104
00:36:05,349 --> 00:36:03,599
some trends that emerge uh the material

1105
00:36:07,589 --> 00:36:05,359
appears to get darker in its

1106
00:36:09,990 --> 00:36:07,599
reflectivity as you go further out into

1107
00:36:11,910 --> 00:36:10,000
the solar system so as we ex as we go

1108
00:36:13,750 --> 00:36:11,920
from the inner edge of the asteroid belt

1109
00:36:15,750 --> 00:36:13,760
all the way out to its to its outer

1110
00:36:18,790 --> 00:36:15,760
extent you can see that the material is

1111
00:36:20,390 --> 00:36:18,800
becoming in general uh lower in albedo

1112
00:36:22,470 --> 00:36:20,400
and we believe that means that this is

1113
00:36:24,550 --> 00:36:22,480

where some of the most uh primitive

1114
00:36:26,790 --> 00:36:24,560
material lies in the outer parts of the

1115
00:36:28,470 --> 00:36:26,800
of the asteroid belt

1116
00:36:30,470 --> 00:36:28,480
but occasionally some of it does make

1117
00:36:32,310 --> 00:36:30,480
its way to the earth

1118
00:36:34,150 --> 00:36:32,320
so uh one of the other things that we've

1119
00:36:35,990 --> 00:36:34,160
looked at is when we take the collection

1120
00:36:37,270 --> 00:36:36,000
now instead of main valve asteroids when

1121
00:36:38,550 --> 00:36:37,280
we go back to the near earth object

1122
00:36:40,790 --> 00:36:38,560
population because this is the

1123
00:36:42,310 --> 00:36:40,800
population that is actually capable of

1124
00:36:43,349 --> 00:36:42,320
reaching the earth itself in the present

1125
00:36:45,589 --> 00:36:43,359
day

1126
00:36:47,990 --> 00:36:45,599
we can look at the different categories

1127
00:36:50,390 --> 00:36:48,000
of earth asteroids and so again plotting

1128
00:36:52,310 --> 00:36:50,400
semi-major axis versus

1129
00:36:54,550 --> 00:36:52,320
orbital inclination so again the tilting

1130
00:36:56,150 --> 00:36:54,560
of the orbit or its eccentricity which

1131
00:36:58,069 --> 00:36:56,160
is essentially how elliptical the orbit

1132
00:36:59,990 --> 00:36:58,079
is there are some trends when we look at

1133
00:37:02,230 --> 00:37:00,000
the albedos we can see that near-earth

1134
00:37:03,829 --> 00:37:02,240
asteroids that extend in their orbits

1135
00:37:05,510 --> 00:37:03,839
that have orbits that carry them further

1136
00:37:07,589 --> 00:37:05,520
out into the asteroid belt they tend on

1137
00:37:09,190 --> 00:37:07,599
average to have lower reflectivities

1138
00:37:11,270 --> 00:37:09,200

than the ones that have more circular

1139
00:37:13,270 --> 00:37:11,280
and more earth-like orbits so that's

1140
00:37:16,390 --> 00:37:13,280
another general trend

1141
00:37:17,270 --> 00:37:16,400
that we found using the neo-wise data

1142
00:37:18,790 --> 00:37:17,280
but

1143
00:37:20,390 --> 00:37:18,800
we'd really like to like i said we'd

1144
00:37:22,310 --> 00:37:20,400
really like to understand exactly the

1145
00:37:24,630 --> 00:37:22,320
nature of this material and and how it

1146
00:37:26,870 --> 00:37:24,640
gets transported to the earth uh from an

1147
00:37:29,109 --> 00:37:26,880
origins perspective i think so again

1148
00:37:30,550 --> 00:37:29,119
these these objects are are uh things

1149
00:37:33,190 --> 00:37:30,560
that have been altered by the presence

1150
00:37:35,270 --> 00:37:33,200
of water throughout their their matrices

1151
00:37:36,870 --> 00:37:35,280
and at present they do contain materials

1152
00:37:37,910 --> 00:37:36,880
such as phyllosilicates in other words

1153
00:37:40,150 --> 00:37:37,920
clays

1154
00:37:41,430 --> 00:37:40,160
as well as amino acids so really

1155
00:37:44,310 --> 00:37:41,440
exciting from an origins of life

1156
00:37:46,310 --> 00:37:44,320
perspective uh to see that these objects

1157
00:37:48,150 --> 00:37:46,320
have such complex chemistry

1158
00:37:49,750 --> 00:37:48,160
okay so now let's look at a little bit

1159
00:37:51,109 --> 00:37:49,760
of the delivery mechanisms just so you

1160
00:37:53,190 --> 00:37:51,119
have an understanding of how this

1161
00:37:55,270 --> 00:37:53,200
material does arrive at the earth uh or

1162
00:37:57,270 --> 00:37:55,280
how we think it arrives at the earth

1163
00:37:58,870 --> 00:37:57,280

in the present epoch

1164
00:38:00,230 --> 00:37:58,880
now i had mentioned before that when

1165
00:38:01,990 --> 00:38:00,240
something is in the main asteroid belt

1166
00:38:03,510 --> 00:38:02,000
it stays there on average for billions

1167
00:38:05,510 --> 00:38:03,520
of years most of the time that's what

1168
00:38:06,790 --> 00:38:05,520
happens however there are a couple of

1169
00:38:08,630 --> 00:38:06,800
exceptions

1170
00:38:10,870 --> 00:38:08,640
it is possible to move through the main

1171
00:38:12,390 --> 00:38:10,880
asteroid belt and make it into near

1172
00:38:13,829 --> 00:38:12,400
object space

1173
00:38:16,630 --> 00:38:13,839
via a couple of different important

1174
00:38:17,910 --> 00:38:16,640
mechanisms one is called yarkovsky drift

1175
00:38:19,430 --> 00:38:17,920
and i'll explain that in a minute and

1176
00:38:21,829 --> 00:38:19,440
the other is through resonances with

1177
00:38:23,190 --> 00:38:21,839
planets so uh kind of a broad way to

1178
00:38:25,430 --> 00:38:23,200
think about it is the influence of

1179
00:38:26,950 --> 00:38:25,440
sunlight and the influence of gravity

1180
00:38:28,470 --> 00:38:26,960
let's look at the first one here and

1181
00:38:29,990 --> 00:38:28,480
these slides are from a colleague of

1182
00:38:31,510 --> 00:38:30,000
mine who i thought did a really nice job

1183
00:38:33,349 --> 00:38:31,520
of illustrating this

1184
00:38:35,030 --> 00:38:33,359
you can imagine that

1185
00:38:36,550 --> 00:38:35,040
there's something that happens to

1186
00:38:37,670 --> 00:38:36,560
asteroids when they get heated up by the

1187
00:38:39,910 --> 00:38:37,680
sun

1188
00:38:42,390 --> 00:38:39,920

the conservation of energy requires that

1189
00:38:44,470 --> 00:38:42,400
the the energy has to go somewhere

1190
00:38:47,270 --> 00:38:44,480
energy is absorbed by an asteroid and

1191
00:38:49,589 --> 00:38:47,280
that can cause it to uh to basically

1192
00:38:50,710 --> 00:38:49,599
have a essentially a recoil action if

1193
00:38:52,870 --> 00:38:50,720
you will

1194
00:38:55,589 --> 00:38:52,880
as the sunlight is is absorbed and then

1195
00:38:57,030 --> 00:38:55,599
re-radiated as the asteroid rotates

1196
00:38:58,550 --> 00:38:57,040
and that actually kind of causes a

1197
00:39:00,950 --> 00:38:58,560
little kick to its orbit and it can

1198
00:39:02,870 --> 00:39:00,960
actually push the object into a spiral

1199
00:39:04,310 --> 00:39:02,880
inward or outward in other words it

1200
00:39:06,790 --> 00:39:04,320
changes the orbit

1201
00:39:08,069 --> 00:39:06,800
even just that faint effective sunlight

1202
00:39:09,829 --> 00:39:08,079
being absorbed by the object and

1203
00:39:12,310 --> 00:39:09,839
re-radiated at a certain time of its

1204
00:39:14,069 --> 00:39:12,320
local day is enough to change its orbit

1205
00:39:16,470 --> 00:39:14,079
now it takes a very long time for this

1206
00:39:18,790 --> 00:39:16,480
effect to happen this is not fast

1207
00:39:20,870 --> 00:39:18,800
the saxon very slow time scales but it's

1208
00:39:23,190 --> 00:39:20,880
enough to cause gradual drifting of the

1209
00:39:25,589 --> 00:39:23,200
object's orbits and when that happens

1210
00:39:26,790 --> 00:39:25,599
now gravitational resonances can take

1211
00:39:28,310 --> 00:39:26,800
over here and i've got a couple of

1212
00:39:31,190 --> 00:39:28,320
examples of what i mean when i say

1213
00:39:33,510 --> 00:39:31,200

resonances uh this is an example of what

1214
00:39:35,349 --> 00:39:33,520
we would call a two to one resonance so

1215
00:39:37,109 --> 00:39:35,359
imagine if you're swinging on a swing

1216
00:39:38,470 --> 00:39:37,119
set and you you kick your legs and if

1217
00:39:41,030 --> 00:39:38,480
you kick your legs at just the right

1218
00:39:42,630 --> 00:39:41,040
point in your swing you'll go higher and

1219
00:39:45,109 --> 00:39:42,640
higher and higher well the same thing

1220
00:39:46,950 --> 00:39:45,119
happens with planets and asteroids once

1221
00:39:49,109 --> 00:39:46,960
objects orbits get locked into certain

1222
00:39:51,589 --> 00:39:49,119
classes of resonances if you put an

1223
00:39:53,829 --> 00:39:51,599
asteroid near these planets now what

1224
00:39:55,910 --> 00:39:53,839
will happen is its eccentricity the the

1225
00:39:57,589 --> 00:39:55,920
squashiness of the orbit if you will can

1226
00:39:59,589 --> 00:39:57,599
get pumped up and can get can get

1227
00:40:01,670 --> 00:39:59,599
increased dramatically and that can

1228
00:40:03,190 --> 00:40:01,680
really change the orbit fast

1229
00:40:04,790 --> 00:40:03,200
so basically you've got a couple of

1230
00:40:06,870 --> 00:40:04,800
different classes of resonance that

1231
00:40:08,470 --> 00:40:06,880
resonances that can happen with planets

1232
00:40:09,990 --> 00:40:08,480
in our solar system

1233
00:40:12,790 --> 00:40:10,000
and when asteroids get into these

1234
00:40:15,270 --> 00:40:12,800
resonant regions uh they can basically

1235
00:40:16,630 --> 00:40:15,280
get acted upon just like a slingshot

1236
00:40:18,550 --> 00:40:16,640
and here's another example of a

1237
00:40:20,470 --> 00:40:18,560
different type of resonance uh in this

1238
00:40:22,470 --> 00:40:20,480

case the two planets start out out of

1239
00:40:24,550 --> 00:40:22,480
resonance but here now you can see the

1240
00:40:26,309 --> 00:40:24,560
effects of them being in resonance

1241
00:40:29,270 --> 00:40:26,319
you can see their aphelia they reach

1242
00:40:31,430 --> 00:40:29,280
appelia and perihelia at the same time

1243
00:40:33,670 --> 00:40:31,440
and that can again cause this really

1244
00:40:35,829 --> 00:40:33,680
dramatic effect on an asteroid's orbit

1245
00:40:38,309 --> 00:40:35,839
if it just gets into the wrong place

1246
00:40:40,069 --> 00:40:38,319
in between these planets here so like a

1247
00:40:42,230 --> 00:40:40,079
slingshot all of a sudden now the orbit

1248
00:40:43,990 --> 00:40:42,240
can change really quickly

1249
00:40:46,069 --> 00:40:44,000
so here's an example of this if we look

1250
00:40:48,630 --> 00:40:46,079
at a certain region of the main asteroid

1251
00:40:49,990 --> 00:40:48,640
belt in semi-major axis so distance from

1252
00:40:51,430 --> 00:40:50,000
the sun roughly

1253
00:40:53,349 --> 00:40:51,440
it was one way to think of it versus the

1254
00:40:55,829 --> 00:40:53,359
object's eccentricity so how round is

1255
00:40:57,910 --> 00:40:55,839
the orbit uh if we start off with a set

1256
00:40:59,829 --> 00:40:57,920
of test asteroids here and we let them

1257
00:41:02,470 --> 00:40:59,839
evolve you can see when they cross into

1258
00:41:04,470 --> 00:41:02,480
these gravitational resonances which are

1259
00:41:06,710 --> 00:41:04,480
marked out here in green now you can see

1260
00:41:09,270 --> 00:41:06,720
the eccentricities change very quickly

1261
00:41:10,790 --> 00:41:09,280
and the asteroids can can dramatically

1262
00:41:12,230 --> 00:41:10,800
change their orbits

1263
00:41:15,270 --> 00:41:12,240

and what this means for the nearest

1264
00:41:17,670 --> 00:41:15,280
asteroids is that you can start off here

1265
00:41:19,430 --> 00:41:17,680
and in a certain region of space a

1266
00:41:21,349 --> 00:41:19,440
certain orbit and now you can get

1267
00:41:22,870 --> 00:41:21,359
involved very quickly

1268
00:41:25,349 --> 00:41:22,880
on time scales of just a few million

1269
00:41:27,829 --> 00:41:25,359
years into planet crossing orbits and

1270
00:41:29,910 --> 00:41:27,839
now you can have impacts

1271
00:41:31,670 --> 00:41:29,920
so in conclusion i would say small

1272
00:41:33,109 --> 00:41:31,680
bodies influence life on earth and

1273
00:41:35,270 --> 00:41:33,119
that's why they're interesting from both

1274
00:41:36,710 --> 00:41:35,280
a hazard perspective as well as an

1275
00:41:38,309 --> 00:41:36,720
origins perspective so with that i'll

1276
00:41:41,430 --> 00:41:38,319
stop here and

1277
00:41:41,440 --> 00:41:46,150
[Applause]

1278
00:42:01,589 --> 00:41:47,829
wow thank you very much that was an

1279
00:42:11,030 --> 00:42:02,870
all right

1280
00:42:14,550 --> 00:42:12,790
thank you so much for your talk i was

1281
00:42:16,550 --> 00:42:14,560
really curious about

1282
00:42:19,430 --> 00:42:16,560
when you were specifying like the nasa

1283
00:42:21,829 --> 00:42:19,440
wanting 90 of um near-earth objects

1284
00:42:23,109 --> 00:42:21,839
being detected um how do you establish

1285
00:42:24,790 --> 00:42:23,119
those thresholds when you don't know

1286
00:42:26,950 --> 00:42:24,800
what's left out there

1287
00:42:29,030 --> 00:42:26,960
that's a really really really important

1288
00:42:30,870 --> 00:42:29,040

question and there are a couple of ways

1289
00:42:32,630 --> 00:42:30,880
that we answer that

1290
00:42:34,390 --> 00:42:32,640
one is what we call the re-detection

1291
00:42:36,150 --> 00:42:34,400
method so in other words each time we

1292
00:42:38,230 --> 00:42:36,160
discover an asteroid we give it a name

1293
00:42:41,349 --> 00:42:38,240
and we can keep track of it so one way

1294
00:42:43,109 --> 00:42:41,359
to test this is to see how often we

1295
00:42:45,030 --> 00:42:43,119
come up with objects that we've seen

1296
00:42:46,950 --> 00:42:45,040
before in other words

1297
00:42:48,309 --> 00:42:46,960
if we keep seeing objects and now after

1298
00:42:49,829 --> 00:42:48,319
a certain period of time we just keep

1299
00:42:51,670 --> 00:42:49,839
finding ones that we've seen over and

1300
00:42:53,910 --> 00:42:51,680
over and over again and we stop finding

1301
00:42:55,910 --> 00:42:53,920
new ones that's a clue that maybe we're

1302
00:42:57,510 --> 00:42:55,920
starting to run out of objects

1303
00:42:58,790 --> 00:42:57,520
but it could also mean that our survey

1304
00:43:00,870 --> 00:42:58,800
is simply not very sensitive that's

1305
00:43:02,710 --> 00:43:00,880
another possibility so to rule that out

1306
00:43:04,309 --> 00:43:02,720
we have a second technique that we use

1307
00:43:06,390 --> 00:43:04,319
where you essentially make a synthetic

1308
00:43:08,550 --> 00:43:06,400
population of asteroids so you assign

1309
00:43:10,790 --> 00:43:08,560
them synthetic orbits and sizes and so

1310
00:43:13,030 --> 00:43:10,800
forth and you essentially build a model

1311
00:43:15,270 --> 00:43:13,040
of your survey you basically sort of

1312
00:43:16,790 --> 00:43:15,280
play a movie if you will of

1313
00:43:18,309 --> 00:43:16,800

using the synthetic population of

1314
00:43:20,710 --> 00:43:18,319
asteroids and you play it through your

1315
00:43:22,309 --> 00:43:20,720
survey and you see what the synthetic

1316
00:43:23,510 --> 00:43:22,319
survey

1317
00:43:25,430 --> 00:43:23,520
actually comes out with and then you

1318
00:43:28,150 --> 00:43:25,440
compare it to what you actually saw and

1319
00:43:29,829 --> 00:43:28,160
you tune your input population until

1320
00:43:31,589 --> 00:43:29,839
these two things match essentially and

1321
00:43:32,950 --> 00:43:31,599
then that tells you okay this is how

1322
00:43:34,390 --> 00:43:32,960
many objects are actually out there in

1323
00:43:35,829 --> 00:43:34,400
the population and then this is the

1324
00:43:36,630 --> 00:43:35,839
fraction that we we believe that we

1325
00:43:37,829 --> 00:43:36,640
found

1326
00:43:39,589 --> 00:43:37,839
so in other words there's a couple of

1327
00:43:41,349 --> 00:43:39,599
ways that we can use to get at what we

1328
00:43:42,710 --> 00:43:41,359
think is really there

1329
00:43:44,630 --> 00:43:42,720
and they work

1330
00:43:45,829 --> 00:43:44,640
uh like i said we're pretty sure at this

1331
00:43:47,670 --> 00:43:45,839
point we found the majority of the

1332
00:43:48,390 --> 00:43:47,680
really big nearest asteroids and we

1333
00:43:50,309 --> 00:43:48,400
think we're somewhere in the

1334
00:43:53,109 --> 00:43:50,319
neighborhood of 30 to 40 percent for the

1335
00:43:58,630 --> 00:43:53,119
the 140 meter class objects

1336
00:44:02,790 --> 00:44:00,550
yes it made sense thank you

1337
00:44:04,630 --> 00:44:02,800
okay thanks

1338
00:44:06,710 --> 00:44:04,640

hi dr mainzer thank you so much for the

1339
00:44:09,030 --> 00:44:06,720
talk it was really interesting

1340
00:44:10,150 --> 00:44:09,040
i had a quick question on

1341
00:44:13,750 --> 00:44:10,160
um

1342
00:44:17,030 --> 00:44:13,760
basically the chelyabinsk uh impact you

1343
00:44:18,470 --> 00:44:17,040
had said something the effect of it

1344
00:44:20,230 --> 00:44:18,480
we thought that we had tracked something

1345
00:44:21,430 --> 00:44:20,240
that wouldn't come anywhere close and

1346
00:44:23,109 --> 00:44:21,440
then it turned out there was something

1347
00:44:24,630 --> 00:44:23,119
that we didn't realize that was sort of

1348
00:44:25,910 --> 00:44:24,640
out of the blue i think you said it was

1349
00:44:28,150 --> 00:44:25,920
the direction of the sun or something

1350
00:44:30,630 --> 00:44:28,160
like that so i guess my question is to

1351
00:44:33,750 --> 00:44:30,640
what extent do we have an estimate of

1352
00:44:36,710 --> 00:44:33,760
similar situations happening where

1353
00:44:38,790 --> 00:44:36,720
we might get misled about uh potential

1354
00:44:40,550 --> 00:44:38,800
impacts or things like that

1355
00:44:42,150 --> 00:44:40,560
yeah this is uh so this is a key

1356
00:44:44,230 --> 00:44:42,160
question for an object of the size of

1357
00:44:46,150 --> 00:44:44,240
the chevy vinci impactor at about 17 to

1358
00:44:48,710 --> 00:44:46,160
20 meters across we only know a few

1359
00:44:50,550 --> 00:44:48,720
percent of those objects are present

1360
00:44:52,790 --> 00:44:50,560
so it is they're just really hard to

1361
00:44:54,390 --> 00:44:52,800
find because they are faint we have to

1362
00:44:56,309 --> 00:44:54,400
wait until they get really close until

1363
00:44:57,990 --> 00:44:56,319

we can spot them at all and in the case

1364
00:45:00,069 --> 00:44:58,000
of this particular object the direction

1365
00:45:02,630 --> 00:45:00,079
that it came from as it made that final

1366
00:45:03,829 --> 00:45:02,640
plunge uh really was nearly in the

1367
00:45:05,750 --> 00:45:03,839
direction of the sun and that's a

1368
00:45:07,670 --> 00:45:05,760
direction our telescopes just can't look

1369
00:45:09,430 --> 00:45:07,680
because the sun is so bright

1370
00:45:10,870 --> 00:45:09,440
so yes it can definitely happen that's

1371
00:45:12,790 --> 00:45:10,880
why we're trying to expand our search

1372
00:45:14,230 --> 00:45:12,800
capabilities so that we have more

1373
00:45:17,190 --> 00:45:14,240
telescopes looking in more different

1374
00:45:19,270 --> 00:45:17,200
directions with greater sensitivity that

1375
00:45:20,870 --> 00:45:19,280
said i mean we still can't look right in

1376
00:45:22,950 --> 00:45:20,880
those regions very close to the sun

1377
00:45:25,030 --> 00:45:22,960
that's really hard to do so with the

1378
00:45:26,550 --> 00:45:25,040
surveyor we're going to try to survey um

1379
00:45:28,710 --> 00:45:26,560
pretty close we'll get to within about

1380
00:45:30,950 --> 00:45:28,720
45 degrees of the sun

1381
00:45:33,030 --> 00:45:30,960
on the sky but uh but that's

1382
00:45:34,390 --> 00:45:33,040
it's it's still we'll expand our

1383
00:45:35,510 --> 00:45:34,400
capability but they're definitely still

1384
00:45:40,870 --> 00:45:35,520
going to be objects where we're not

1385
00:45:45,109 --> 00:45:42,470
dr mainzer thank you for your talk so

1386
00:45:47,430 --> 00:45:45,119
far and uh wanted to ask if you could

1387
00:45:49,589 --> 00:45:47,440
address the question around earthbound

1388
00:45:51,990 --> 00:45:49,599

observations of neos

1389
00:45:54,309 --> 00:45:52,000
with respect to mega constellations like

1390
00:45:55,829 --> 00:45:54,319
starlink or oneweb and what the impact

1391
00:45:58,390 --> 00:45:55,839
of those would be obviously it'd be

1392
00:45:59,670 --> 00:45:58,400
great to be more space-based but that's

1393
00:46:00,390 --> 00:45:59,680
really expensive but if you could

1394
00:46:02,550 --> 00:46:00,400
address

1395
00:46:04,630 --> 00:46:02,560
earth-based observations and the impact

1396
00:46:06,470 --> 00:46:04,640
on these mega constellations

1397
00:46:07,910 --> 00:46:06,480
absolutely and that's a very important

1398
00:46:09,510 --> 00:46:07,920
point and i have some colleagues who are

1399
00:46:11,349 --> 00:46:09,520
doing some really wonderful work on this

1400
00:46:13,190 --> 00:46:11,359
uh to try to understand the impacts and

1401
00:46:15,349 --> 00:46:13,200
quantify them better i mean certainly

1402
00:46:17,270 --> 00:46:15,359
from a from an observer's perspective

1403
00:46:18,870 --> 00:46:17,280
more things that are potential sources

1404
00:46:20,390 --> 00:46:18,880
of confusion are not good it doesn't

1405
00:46:21,349 --> 00:46:20,400
make the problem easier let's put it

1406
00:46:23,910 --> 00:46:21,359
that way

1407
00:46:25,670 --> 00:46:23,920
it can only make it harder so it's uh

1408
00:46:27,349 --> 00:46:25,680
it's definitely not helping

1409
00:46:30,230 --> 00:46:27,359
and the more objects there are the more

1410
00:46:33,510 --> 00:46:30,240
confusion that they will cause

1411
00:46:35,589 --> 00:46:33,520
so it's it's not a good trend

1412
00:46:37,030 --> 00:46:35,599
there is a paper that just came out by

1413
00:46:38,390 --> 00:46:37,040

some colleagues

1414
00:46:39,990 --> 00:46:38,400
working with the zwiki transient

1415
00:46:42,069 --> 00:46:40,000
facility

1416
00:46:43,750 --> 00:46:42,079
who have tried to start quantifying you

1417
00:46:46,550 --> 00:46:43,760
know what they're seeing today

1418
00:46:49,030 --> 00:46:46,560
and um yeah i mean it is it is really a

1419
00:46:50,309 --> 00:46:49,040
source of concern i think because uh it

1420
00:46:52,950 --> 00:46:50,319
just certainly doesn't make the problem

1421
00:46:54,790 --> 00:46:52,960
any easier right now uh the paper from

1422
00:46:56,230 --> 00:46:54,800
the ztf team indicates that you know

1423
00:46:57,750 --> 00:46:56,240
they can they can do a fairly effective

1424
00:46:59,030 --> 00:46:57,760
job of masking them out if they know

1425
00:47:01,270 --> 00:46:59,040
where they are

1426
00:47:02,710 --> 00:47:01,280
but as the constellations grow it's just

1427
00:47:03,910 --> 00:47:02,720
going to get to be a harder problem

1428
00:47:05,670 --> 00:47:03,920
absolutely

1429
00:47:08,950 --> 00:47:05,680
so i would say not good is the short

1430
00:47:14,069 --> 00:47:10,550
uh we've got a couple of questions

1431
00:47:16,630 --> 00:47:14,079
coming in from online uh one question is

1432
00:47:19,990 --> 00:47:16,640
in light of the influence of small

1433
00:47:22,150 --> 00:47:20,000
bodies and delivery of the objects

1434
00:47:24,069 --> 00:47:22,160
and the materials in them to earth and

1435
00:47:26,470 --> 00:47:24,079
places like that what are your views on

1436
00:47:28,710 --> 00:47:26,480
the theory of panspermia

1437
00:47:31,670 --> 00:47:28,720
oh boy well i'm certainly no expert on

1438
00:47:33,750 --> 00:47:31,680

the origins of life but i will say it's

1439
00:47:35,910 --> 00:47:33,760
just really fascinating to think about

1440
00:47:38,150 --> 00:47:35,920
uh there's a whole set of really really

1441
00:47:39,270 --> 00:47:38,160
interesting experiments that just show

1442
00:47:41,190 --> 00:47:39,280
how

1443
00:47:43,589 --> 00:47:41,200
complex chemistry grows on the surfaces

1444
00:47:46,069 --> 00:47:43,599
of dust grains uh and

1445
00:47:47,910 --> 00:47:46,079
dr ishii showed that i showed that slide

1446
00:47:49,670 --> 00:47:47,920
from her for her imaging of a dust

1447
00:47:51,589 --> 00:47:49,680
particle well basically we think that

1448
00:47:53,990 --> 00:47:51,599
these are wonderful surfaces

1449
00:47:55,589 --> 00:47:54,000
for for chemicals to to meet up and

1450
00:47:56,950 --> 00:47:55,599
become more complex chemistry

1451
00:47:59,190 --> 00:47:56,960
essentially

1452
00:48:02,390 --> 00:47:59,200
so the surfaces of dust grains are great

1453
00:48:03,270 --> 00:48:02,400
nucleation sites for for uh chemistry to

1454
00:48:05,109 --> 00:48:03,280
happen

1455
00:48:06,790 --> 00:48:05,119
especially as they're irradiated by

1456
00:48:08,069 --> 00:48:06,800
their host stars

1457
00:48:09,270 --> 00:48:08,079
so

1458
00:48:11,190 --> 00:48:09,280
you know

1459
00:48:12,950 --> 00:48:11,200
could life have evolved elsewhere i mean

1460
00:48:14,710 --> 00:48:12,960
there's so many planets now that we know

1461
00:48:15,990 --> 00:48:14,720
about it it seems to me that it would be

1462
00:48:18,069 --> 00:48:16,000
very probable

1463
00:48:19,910 --> 00:48:18,079

exactly the mechanisms though that

1464
00:48:21,430 --> 00:48:19,920
that's a mystery and i sure hope people

1465
00:48:26,230 --> 00:48:21,440
will work on that because i think it's

1466
00:48:31,190 --> 00:48:28,790
awesome uh and another question from

1467
00:48:33,510 --> 00:48:31,200
youtube uh dr mainzer you mentioned that

1468
00:48:35,190 --> 00:48:33,520
these small near-earth asteroids contain

1469
00:48:37,510 --> 00:48:35,200
amino acids

1470
00:48:39,030 --> 00:48:37,520
as a microbiology phd student my

1471
00:48:41,430 --> 00:48:39,040
question is how are the building blocks

1472
00:48:43,109 --> 00:48:41,440
of life incorporated into asteroids so

1473
00:48:45,109 --> 00:48:43,119
very similar question

1474
00:48:46,710 --> 00:48:45,119
right okay so we are definitely testing

1475
00:48:47,990 --> 00:48:46,720
the boundaries of my knowledge here but

1476
00:48:49,190 --> 00:48:48,000
i'll tell you what i know which is

1477
00:48:51,829 --> 00:48:49,200
basically that

1478
00:48:53,589 --> 00:48:51,839
um that yeah that we know that we can

1479
00:48:55,829 --> 00:48:53,599
study these objects as they as they come

1480
00:48:57,510 --> 00:48:55,839
to earth in the form of meteorites um so

1481
00:49:00,549 --> 00:48:57,520
like i said here this this particular

1482
00:49:02,790 --> 00:49:00,559
object uh is uh is a well-known

1483
00:49:05,510 --> 00:49:02,800
primitive asteroid or

1484
00:49:07,829 --> 00:49:05,520
meteorite called allende and you can see

1485
00:49:10,069 --> 00:49:07,839
there's a there's a lot of small

1486
00:49:11,190 --> 00:49:10,079
kind of whitish markers inside it there

1487
00:49:13,030 --> 00:49:11,200
i don't know if there are features in

1488
00:49:14,230 --> 00:49:13,040

there those are called chondrules and

1489
00:49:15,750 --> 00:49:14,240
these are these are things that are

1490
00:49:17,510 --> 00:49:15,760
really left over from the very beginning

1491
00:49:19,030 --> 00:49:17,520
of the solar system's formation so

1492
00:49:20,870 --> 00:49:19,040
they're quite old

1493
00:49:22,549 --> 00:49:20,880
but in an object like this you can still

1494
00:49:25,430 --> 00:49:22,559
find evidence of of this complex

1495
00:49:27,190 --> 00:49:25,440
chemistry so uh perhaps it means that

1496
00:49:29,670 --> 00:49:27,200
this this process got started quite

1497
00:49:31,670 --> 00:49:29,680
early in our solar system's formation

1498
00:49:32,870 --> 00:49:31,680
within you know the first billion years

1499
00:49:34,710 --> 00:49:32,880
or so

1500
00:49:35,750 --> 00:49:34,720
again this is really at the boundary of

1501
00:49:38,390 --> 00:49:35,760
what i know

1502
00:49:39,829 --> 00:49:38,400
but i would say that um

1503
00:49:41,270 --> 00:49:39,839
it's very probable that this is a

1504
00:49:43,589 --> 00:49:41,280
process that happens in other solar

1505
00:49:45,829 --> 00:49:43,599
systems i would think

1506
00:49:48,069 --> 00:49:45,839
and exactly to what degree it influenced

1507
00:49:49,190 --> 00:49:48,079
the develop of chemistry here on earth i

1508
00:49:50,390 --> 00:49:49,200
don't know

1509
00:49:54,390 --> 00:49:50,400
but it's definitely a fascinating

1510
00:49:58,309 --> 00:49:56,630
hi so my name is michael schaible i am a

1511
00:49:59,190 --> 00:49:58,319
research scientist here at georgia tech

1512
00:49:59,910 --> 00:49:59,200
and

1513
00:50:01,270 --> 00:49:59,920

i

1514
00:50:02,470 --> 00:50:01,280
so so

1515
00:50:04,710 --> 00:50:02,480
i wanted to

1516
00:50:07,030 --> 00:50:04,720
just poke a little bit at sort of you

1517
00:50:08,150 --> 00:50:07,040
did this this uh this movie

1518
00:50:12,790 --> 00:50:08,160
uh

1519
00:50:15,750 --> 00:50:12,800
i was wondering how your work sort of

1520
00:50:18,150 --> 00:50:15,760
fits into the small comets world

1521
00:50:21,030 --> 00:50:18,160
um you know how likely is it that we're

1522
00:50:23,589 --> 00:50:21,040
going to have uh an earth crossing small

1523
00:50:26,390 --> 00:50:23,599
comet that we just don't know about

1524
00:50:28,549 --> 00:50:26,400
right um yeah that's a that's a really

1525
00:50:30,230 --> 00:50:28,559
interesting point so so the good news is

1526
00:50:32,309 --> 00:50:30,240
we know that like i said these really

1527
00:50:33,589 --> 00:50:32,319
large uh globally catastrophic events

1528
00:50:35,750 --> 00:50:33,599
they have to be infrequent or we

1529
00:50:37,510 --> 00:50:35,760
wouldn't be here i i would say

1530
00:50:39,190 --> 00:50:37,520
um but there are a lot of smaller pieces

1531
00:50:40,950 --> 00:50:39,200
out there and and we do our best to keep

1532
00:50:42,470 --> 00:50:40,960
track of them um but occasionally some

1533
00:50:45,190 --> 00:50:42,480
of them you know make it into the inner

1534
00:50:47,109 --> 00:50:45,200
solar system um i think

1535
00:50:48,790 --> 00:50:47,119
you know the the chance that the saving

1536
00:50:50,069 --> 00:50:48,800
grace with the comets is that in terms

1537
00:50:51,750 --> 00:50:50,079
of the ones that make it into the inner

1538
00:50:53,510 --> 00:50:51,760

part of the solar system they are far

1539
00:50:54,630 --> 00:50:53,520
fewer in number than the nearest

1540
00:50:56,870 --> 00:50:54,640
asteroids

1541
00:50:58,950 --> 00:50:56,880
so in other words uh even though comets

1542
00:51:00,549 --> 00:50:58,960
can on average be a lot larger than a

1543
00:51:02,309 --> 00:51:00,559
typical mirror of asteroid that that

1544
00:51:04,230 --> 00:51:02,319
we're keeping track of

1545
00:51:06,230 --> 00:51:04,240
uh they tend to be

1546
00:51:07,589 --> 00:51:06,240
uh they're bigger they move really fast

1547
00:51:09,990 --> 00:51:07,599
with respect to the earth so they can

1548
00:51:11,190 --> 00:51:10,000
pack a huge punch but saving grace is

1549
00:51:12,870 --> 00:51:11,200
there there are fewer of them that

1550
00:51:14,870 --> 00:51:12,880
really make it into this part of the

1551
00:51:16,390 --> 00:51:14,880
space right near the earth so so that's

1552
00:51:17,750 --> 00:51:16,400
the saving grace but that said we still

1553
00:51:19,510 --> 00:51:17,760
have to keep an eye out for them they

1554
00:51:21,589 --> 00:51:19,520
are yeah that's great so so do you use

1555
00:51:23,190 --> 00:51:21,599
the same surveys to look for those or is

1556
00:51:25,109 --> 00:51:23,200
it a different survey

1557
00:51:26,630 --> 00:51:25,119
yeah we're using the same surveys and

1558
00:51:27,990 --> 00:51:26,640
you you raise an interesting point

1559
00:51:29,589 --> 00:51:28,000
should we be doing the survey in the

1560
00:51:31,030 --> 00:51:29,599
same way in other words do you want to

1561
00:51:33,349 --> 00:51:31,040
look on the same part of the sky with

1562
00:51:35,349 --> 00:51:33,359
the same number of revisits and so forth

1563
00:51:36,710 --> 00:51:35,359

should the survey cadence change as a

1564
00:51:38,870 --> 00:51:36,720
result of the orbital elements of the

1565
00:51:40,390 --> 00:51:38,880
thing we're searching for so far the

1566
00:51:42,069 --> 00:51:40,400
good news is that the near-earth

1567
00:51:44,230 --> 00:51:42,079
asteroids tend to have a pretty broad

1568
00:51:45,589 --> 00:51:44,240
distribution on the sky in terms of

1569
00:51:47,589 --> 00:51:45,599
their orbital inclinations in other

1570
00:51:49,750 --> 00:51:47,599
words the tilts of their orbits

1571
00:51:51,670 --> 00:51:49,760
so that's good from the perspective of

1572
00:51:53,190 --> 00:51:51,680
looking for comets which the long period

1573
00:51:55,030 --> 00:51:53,200
comets really are isotropically

1574
00:51:57,349 --> 00:51:55,040
distributed they're all over the place

1575
00:51:59,109 --> 00:51:57,359
so far that means our basic search

1576
00:52:01,510 --> 00:51:59,119
research strategies uh seem to be

1577
00:52:02,950 --> 00:52:01,520
effective at both populations that said

1578
00:52:04,470 --> 00:52:02,960
as we get further along in the survey

1579
00:52:06,069 --> 00:52:04,480
it's possible we could refine things to

1580
00:52:08,150 --> 00:52:06,079
spend more time looking at high

1581
00:52:14,950 --> 00:52:08,160
inclinations possibly kind of depends on

1582
00:52:20,549 --> 00:52:16,230
does that sort of answer the question

1583
00:52:24,069 --> 00:52:22,230
there we go i had to turn the microphone

1584
00:52:27,190 --> 00:52:24,079
on for a second

1585
00:52:30,150 --> 00:52:27,200
all right uh i'm more of a biologist but

1586
00:52:31,430 --> 00:52:30,160
i haven't i uh so i have a question more

1587
00:52:33,750 --> 00:52:31,440
about

1588
00:52:36,549 --> 00:52:33,760

uh how these things might change over

1589
00:52:39,430 --> 00:52:36,559
the course of history um i

1590
00:52:40,950 --> 00:52:39,440
when you were talking about uh it's the

1591
00:52:43,109 --> 00:52:40,960
way when you create a family and the

1592
00:52:45,109 --> 00:52:43,119
family then expands through

1593
00:52:47,910 --> 00:52:45,119
phase space and starts uh becoming

1594
00:52:49,589 --> 00:52:47,920
crossing um seems like that could lead

1595
00:52:53,349 --> 00:52:49,599
to sort of a cluster

1596
00:52:54,230 --> 00:52:53,359
of uh events in time and i'm wondering

1597
00:53:00,549 --> 00:52:54,240
if

1598
00:53:02,390 --> 00:53:00,559
of a constant background of these things

1599
00:53:04,950 --> 00:53:02,400
or if um

1600
00:53:07,589 --> 00:53:04,960
clustered events like that might uh

1601
00:53:09,589 --> 00:53:07,599
occur in time and how much if and if

1602
00:53:10,470 --> 00:53:09,599
those might

1603
00:53:12,870 --> 00:53:10,480
be a

1604
00:53:14,470 --> 00:53:12,880
reasonable part of what happens or if

1605
00:53:15,829 --> 00:53:14,480
just generic background might be a

1606
00:53:17,589 --> 00:53:15,839
bigger deal

1607
00:53:19,030 --> 00:53:17,599
that's a also really interesting and

1608
00:53:20,549 --> 00:53:19,040
there's this period called the late

1609
00:53:22,230 --> 00:53:20,559
heavy bombardment that we think happened

1610
00:53:23,589 --> 00:53:22,240
fairly early on in the solar system's

1611
00:53:25,190 --> 00:53:23,599
formation so kind of in the first

1612
00:53:27,270 --> 00:53:25,200
billion years or so

1613
00:53:29,430 --> 00:53:27,280

where there was a reshuffling that

1614
00:53:32,390 --> 00:53:29,440
happened which sent a volley of of

1615
00:53:34,069 --> 00:53:32,400
impactors into uh into near earth space

1616
00:53:35,910 --> 00:53:34,079
and so the earth was we think kind of

1617
00:53:37,349 --> 00:53:35,920
really pelted with with objects back in

1618
00:53:39,910 --> 00:53:37,359
that period and then it sort of tapered

1619
00:53:41,750 --> 00:53:39,920
off after that but you're right um you

1620
00:53:42,870 --> 00:53:41,760
can have these family forming events and

1621
00:53:45,030 --> 00:53:42,880
if something happens close to a

1622
00:53:47,670 --> 00:53:45,040
resonance it can really affect

1623
00:53:49,430 --> 00:53:47,680
the local in influence or the local flux

1624
00:53:50,790 --> 00:53:49,440
of objects onto the earth so one of the

1625
00:53:52,630 --> 00:53:50,800
things i'm interested in looking at it

1626
00:53:54,309 --> 00:53:52,640
hopefully eventually is to is to try to

1627
00:53:55,829 --> 00:53:54,319
prove that in greater detail

1628
00:53:58,150 --> 00:53:55,839
because it doesn't take a huge object to

1629
00:53:59,910 --> 00:53:58,160
collide to produce a lot of fragments so

1630
00:54:01,270 --> 00:53:59,920
we know sort of the broad brush picture

1631
00:54:03,829 --> 00:54:01,280
of how it happened with the late

1632
00:54:05,430 --> 00:54:03,839
bombardment but the exact specifics of

1633
00:54:06,710 --> 00:54:05,440
what happened since then i think we

1634
00:54:08,390 --> 00:54:06,720
would like to have more data to be able

1635
00:54:12,790 --> 00:54:08,400
to probe that in in greater detail which

1636
00:54:17,430 --> 00:54:14,790
great thank you so much amy for your

1637
00:54:19,270 --> 00:54:17,440
wonderful talk we really all enjoyed it

1638
00:54:21,829 --> 00:54:19,280

um there are a few more questions that

1639
00:54:23,510 --> 00:54:21,839
populated in the chat that we could have

1640
00:54:24,549 --> 00:54:23,520
you take a look at later if you would

1641
00:54:27,349 --> 00:54:24,559
like

1642
00:54:28,870 --> 00:54:27,359
but we will be moving on to our final

1643
00:54:31,589 --> 00:54:28,880
session of

1644
00:54:33,270 --> 00:54:31,599
speakers here

1645
00:55:11,109 --> 00:54:33,280
thank you so much

1646
00:55:15,829 --> 00:55:14,309
great so we can move on to our next

1647
00:55:17,270 --> 00:55:15,839
one is it streaming okay in the blue

1648
00:55:19,670 --> 00:55:17,280
jeans

1649
00:55:21,910 --> 00:55:19,680
okay great um so the third session for

1650
00:55:24,150 --> 00:55:21,920
today is called inside cellular and

1651
00:55:26,230 --> 00:55:24,160
molecular evolution and our first

1652
00:55:28,789 --> 00:55:26,240
presenter will be kvita mintinggay

1653
00:55:30,470 --> 00:55:28,799
presenting on memory and molecules sorry

1654
00:55:46,950 --> 00:55:30,480
molecular memory at the emergence of

1655
00:55:51,829 --> 00:55:49,829
everyone one second

1656
00:55:55,270 --> 00:55:51,839
okay okay and is it focused on this

1657
00:56:00,390 --> 00:55:58,069
oh no it's not

1658
00:56:06,549 --> 00:56:00,400
oh okay here we can do this quickly then

1659
00:56:06,559 --> 00:56:41,349
oh yeah for sure

1660
00:56:45,589 --> 00:56:43,349
hello hi

1661
00:56:47,349 --> 00:56:45,599
um

1662
00:56:49,030 --> 00:56:47,359
let me see

1663
00:56:52,870 --> 00:56:49,040

okay i think this works

1664
00:56:55,109 --> 00:56:52,880
um good morning good afternoon uh i am

1665
00:56:57,589 --> 00:56:55,119
kavita i'm from the williams lab and i

1666
00:56:58,470 --> 00:56:57,599
just want to give today give an overview

1667
00:57:00,150 --> 00:56:58,480
about

1668
00:57:01,750 --> 00:57:00,160
some of the current ideas we have in the

1669
00:57:04,309 --> 00:57:01,760
williams lab about

1670
00:57:06,309 --> 00:57:04,319
molecules and memory um

1671
00:57:08,870 --> 00:57:06,319
and i think memory is something very

1672
00:57:11,030 --> 00:57:08,880
inherent in the origin of life but we

1673
00:57:11,829 --> 00:57:11,040
have but it's very implicit we haven't

1674
00:57:14,630 --> 00:57:11,839
quite

1675
00:57:16,630 --> 00:57:14,640
defined it and hopefully in the next few

1676
00:57:19,349 --> 00:57:16,640
minutes i will try to

1677
00:57:20,789 --> 00:57:19,359
uh demonstrate how we're trying to do

1678
00:57:22,630 --> 00:57:20,799
that um

1679
00:57:24,789 --> 00:57:22,640
so before we go to the origin of life i

1680
00:57:27,030 --> 00:57:24,799
want to just break down the word memory

1681
00:57:28,789 --> 00:57:27,040
uh when we say the word memory we think

1682
00:57:31,349 --> 00:57:28,799
of all these different ideas and

1683
00:57:33,910 --> 00:57:31,359
concepts we think of remembering people

1684
00:57:36,950 --> 00:57:34,950
names

1685
00:57:37,990 --> 00:57:36,960
biologists often associate neurons with

1686
00:57:40,870 --> 00:57:38,000
memories

1687
00:57:42,549 --> 00:57:40,880
some of these molecules memory is often

1688
00:57:45,030 --> 00:57:42,559

the word associated with computers as

1689
00:57:48,150 --> 00:57:45,040
well where we have short term less short

1690
00:57:50,150 --> 00:57:48,160
term and much more long term memories

1691
00:57:52,789 --> 00:57:50,160
at the heart of all of these processes

1692
00:57:55,349 --> 00:57:52,799
though is this idea of acquisition and

1693
00:57:57,510 --> 00:57:55,359
coding and retrieval of information

1694
00:58:00,150 --> 00:57:57,520
information of different kinds

1695
00:58:01,910 --> 00:58:00,160
but the process itself is the same

1696
00:58:03,910 --> 00:58:01,920
across all these different

1697
00:58:06,470 --> 00:58:03,920
formats

1698
00:58:08,950 --> 00:58:06,480
another definition of memory though is

1699
00:58:11,510 --> 00:58:08,960
the ability to record information about

1700
00:58:13,349 --> 00:58:11,520
events and the facility of recalling

1701
00:58:15,109 --> 00:58:13,359
them at a later point

1702
00:58:17,030 --> 00:58:15,119
now this different definition is really

1703
00:58:19,030 --> 00:58:17,040
interesting for biology because biology

1704
00:58:20,630 --> 00:58:19,040
is amazing at remembering things so

1705
00:58:22,710 --> 00:58:20,640
biology is amazing at recording

1706
00:58:25,270 --> 00:58:22,720
information and biology is amazing at

1707
00:58:27,349 --> 00:58:25,280
recalling them and the most i guess

1708
00:58:29,750 --> 00:58:27,359
amazing part of biology is genetic

1709
00:58:32,710 --> 00:58:29,760
memory or nucleic acid memory we have

1710
00:58:34,870 --> 00:58:32,720
information about genes stored over

1711
00:58:37,030 --> 00:58:34,880
um millions and millions of years we

1712
00:58:39,510 --> 00:58:37,040
have infinite information stored as

1713
00:58:41,190 --> 00:58:39,520

identity of these specific molecules

1714
00:58:41,990 --> 00:58:41,200
here acgt

1715
00:58:43,990 --> 00:58:42,000
um

1716
00:58:46,870 --> 00:58:44,000
you in case of rna

1717
00:58:49,270 --> 00:58:46,880
and this form of storage and this type

1718
00:58:50,710 --> 00:58:49,280
of information stored in

1719
00:58:54,309 --> 00:58:50,720
nucleic acids

1720
00:58:56,230 --> 00:58:54,319
is uh called is termed as heredity and

1721
00:58:57,430 --> 00:58:56,240
it's an excellent form of memory in

1722
00:59:00,230 --> 00:58:57,440
biology

1723
00:59:01,589 --> 00:59:00,240
uh for millions and millions of years

1724
00:59:04,470 --> 00:59:01,599
uh what i want to

1725
00:59:05,990 --> 00:59:04,480
demonstrate today is that maybe it's not

1726
00:59:09,030 --> 00:59:06,000
maybe it doesn't stop there maybe it

1727
00:59:10,549 --> 00:59:09,040
goes beyond and when i say beyond i'm

1728
00:59:12,309 --> 00:59:10,559
we mean

1729
00:59:14,870 --> 00:59:12,319
beyond genetic memory we talk about

1730
00:59:18,710 --> 00:59:14,880
non-genetic memory we see that there are

1731
00:59:20,710 --> 00:59:18,720
of ways in biology which are

1732
00:59:23,190 --> 00:59:20,720
which are programmed to record

1733
00:59:26,710 --> 00:59:23,200
information which is not quite which

1734
00:59:28,470 --> 00:59:26,720
doesn't quite reach the genetic um level

1735
00:59:32,069 --> 00:59:28,480
and this is often as histone

1736
00:59:34,470 --> 00:59:32,079
modification dna methylation rna

1737
00:59:35,910 --> 00:59:34,480
changes structural as well as

1738
00:59:39,270 --> 00:59:35,920

um

1739
00:59:41,349 --> 00:59:39,280
molecular changes in the rna and a host

1740
00:59:43,270 --> 00:59:41,359
of other chromatin modifications as well

1741
00:59:45,829 --> 00:59:43,280
and these are forms of memory which are

1742
00:59:46,870 --> 00:59:45,839
less which are less short which are less

1743
00:59:48,950 --> 00:59:46,880
long-term

1744
00:59:50,549 --> 00:59:48,960
but there are still ways of

1745
00:59:53,510 --> 00:59:50,559
ways in which biology records

1746
00:59:54,950 --> 00:59:53,520
information for a period of time

1747
00:59:56,870 --> 00:59:54,960
now we're going to push this a little

1748
00:59:58,870 --> 00:59:56,880
further and

1749
01:00:00,789 --> 00:59:58,880
present a couple of other

1750
01:00:03,349 --> 01:00:00,799
instances in biology where memory is

1751
01:00:05,829 --> 01:00:03,359
recorded but we don't

1752
01:00:07,910 --> 01:00:05,839
traditionally associate with

1753
01:00:10,390 --> 01:00:07,920
memory and i would and we want to

1754
01:00:12,950 --> 01:00:10,400
suggest that maybe these are some of the

1755
01:00:15,430 --> 01:00:12,960
ways in which biology records

1756
01:00:18,470 --> 01:00:15,440
cell signaling pathways so map kinase

1757
01:00:20,630 --> 01:00:18,480
pathways are ways in which cells are

1758
01:00:22,710 --> 01:00:20,640
regulate uh homo

1759
01:00:24,950 --> 01:00:22,720
homeostasis mechanisms where cells are

1760
01:00:29,190 --> 01:00:24,960
capable of detecting the environment

1761
01:00:32,309 --> 01:00:29,200
detecting um um their their situation

1762
01:00:34,390 --> 01:00:32,319
and regulating the um

1763
01:00:36,069 --> 01:00:34,400

regular upregulating or down regulating

1764
01:00:38,230 --> 01:00:36,079
downstream pathways

1765
01:00:40,630 --> 01:00:38,240
uh allosteric regulation which is a much

1766
01:00:43,510 --> 01:00:40,640
more short-term form of memory where we

1767
01:00:45,430 --> 01:00:43,520
have small molecules regulating specific

1768
01:00:47,270 --> 01:00:45,440
metabolic pathways

1769
01:00:49,109 --> 01:00:47,280
and feedback loops of course so these

1770
01:00:50,950 --> 01:00:49,119
may be called short-term memory but

1771
01:00:54,390 --> 01:00:50,960
these are also we

1772
01:00:56,870 --> 01:00:54,400
opposite forms of memory in biology

1773
01:00:58,950 --> 01:00:56,880
pushing that even further and going even

1774
01:01:00,789 --> 01:00:58,960
smaller into the molecular scale we want

1775
01:01:04,309 --> 01:01:00,799
to present things like ion-based

1776
01:01:07,670 --> 01:01:04,319
inheritance now prions are basically our

1777
01:01:09,910 --> 01:01:07,680
indep are proteins misfolded proteins

1778
01:01:12,230 --> 01:01:09,920
which are independent of sequence so

1779
01:01:14,309 --> 01:01:12,240
they essentially have very less to do

1780
01:01:16,309 --> 01:01:14,319
with the particular sequence of amino

1781
01:01:18,470 --> 01:01:16,319
acids sequence of genes that code for

1782
01:01:20,950 --> 01:01:18,480
them they are essentially structural

1783
01:01:23,589 --> 01:01:20,960
pieces of information which can last up

1784
01:01:25,670 --> 01:01:23,599
to sometimes even longer than

1785
01:01:28,630 --> 01:01:25,680
which in last generation sometimes even

1786
01:01:29,829 --> 01:01:28,640
longer than um epigenetics or dna

1787
01:01:31,589 --> 01:01:29,839
methylation

1788
01:01:33,270 --> 01:01:31,599

so there are um

1789
01:01:35,030 --> 01:01:33,280
then this so this is prion-based

1790
01:01:37,270 --> 01:01:35,040
inheritance the second one is quorum

1791
01:01:38,549 --> 01:01:37,280
sensing where we have a different set of

1792
01:01:40,789 --> 01:01:38,559
life bacteria

1793
01:01:43,510 --> 01:01:40,799
which are capable of detecting

1794
01:01:45,510 --> 01:01:43,520
um populations and regulating their

1795
01:01:48,630 --> 01:01:45,520
behavior accordingly now this is

1796
01:01:50,390 --> 01:01:48,640
regulation but i would we would actually

1797
01:01:53,589 --> 01:01:50,400
argue that this is a form of short-term

1798
01:01:56,230 --> 01:01:53,599
memory which can last across generations

1799
01:01:57,829 --> 01:01:56,240
and provide the said organism with some

1800
01:02:01,510 --> 01:01:57,839
kind of

1801
01:02:02,950 --> 01:02:01,520
disadvantage against the environment

1802
01:02:04,789 --> 01:02:02,960
and

1803
01:02:06,789 --> 01:02:04,799
i think this is where

1804
01:02:08,630 --> 01:02:06,799
we want to

1805
01:02:10,950 --> 01:02:08,640
push this boundary even more and say

1806
01:02:12,390 --> 01:02:10,960
okay if biology has so many different

1807
01:02:13,990 --> 01:02:12,400
forms of memory which we don't

1808
01:02:16,309 --> 01:02:14,000
traditionally think of

1809
01:02:18,710 --> 01:02:16,319
maybe memory is something much more

1810
01:02:21,670 --> 01:02:18,720
inherent to biology and maybe this that

1811
01:02:23,670 --> 01:02:21,680
should influence our study into this our

1812
01:02:25,670 --> 01:02:23,680
study of the origin of life

1813
01:02:27,829 --> 01:02:25,680

and hence we are working currently

1814
01:02:29,670 --> 01:02:27,839
within the framework that the origin of

1815
01:02:31,750 --> 01:02:29,680
life is the origin and evolution of

1816
01:02:35,670 --> 01:02:31,760
sophisticated molecular memory which

1817
01:02:39,109 --> 01:02:35,680
goes much which goes way beyond heritage

1818
01:02:40,630 --> 01:02:39,119
this is not something completely new um

1819
01:02:42,549 --> 01:02:40,640
and i would

1820
01:02:45,029 --> 01:02:42,559
actually say that

1821
01:02:46,950 --> 01:02:45,039
all the research into the origin of life

1822
01:02:49,589 --> 01:02:46,960
beginning from the rna world which was i

1823
01:02:51,670 --> 01:02:49,599
think in the 1970s or 80s has been

1824
01:02:53,589 --> 01:02:51,680
trying to look for some kind of memory

1825
01:02:55,990 --> 01:02:53,599
some kind of system self-replicating

1826
01:02:58,309 --> 01:02:56,000
system that records memory that can

1827
01:03:00,549 --> 01:02:58,319
transmit it to the next generation

1828
01:03:02,549 --> 01:03:00,559
uh we are currently looking at uh

1829
01:03:05,109 --> 01:03:02,559
changes in the identity of the molecules

1830
01:03:06,309 --> 01:03:05,119
where we have backbone changes we have

1831
01:03:09,029 --> 01:03:06,319
um

1832
01:03:09,829 --> 01:03:09,039
identity of the bases being changed

1833
01:03:12,710 --> 01:03:09,839
and

1834
01:03:14,390 --> 01:03:12,720
these are essentially i think

1835
01:03:19,990 --> 01:03:14,400
attempts

1836
01:03:21,029 --> 01:03:20,000
try and identify what kind of memory

1837
01:03:22,549 --> 01:03:21,039
existed

1838
01:03:24,390 --> 01:03:22,559

long long ago

1839
01:03:26,309 --> 01:03:24,400
and um

1840
01:03:28,789 --> 01:03:26,319
although they are all

1841
01:03:31,589 --> 01:03:28,799
amazing pieces of research i think

1842
01:03:33,750 --> 01:03:31,599
we also need to open up our uh mind to

1843
01:03:36,069 --> 01:03:33,760
the fact that memory was maybe something

1844
01:03:38,710 --> 01:03:36,079
way beyond heredity maybe it was

1845
01:03:40,870 --> 01:03:38,720
not it was less tied to the identity

1846
01:03:42,789 --> 01:03:40,880
identity of the molecules something more

1847
01:03:44,470 --> 01:03:42,799
to do with the environmental processes

1848
01:03:47,109 --> 01:03:44,480
the regulation the recording of

1849
01:03:50,230 --> 01:03:47,119
information in different ways

1850
01:03:52,710 --> 01:03:50,240
the williams lab right now is working on

1851
01:03:54,150 --> 01:03:52,720
a system where we can study the

1852
01:03:56,950 --> 01:03:54,160
evolution of memory which is

1853
01:03:58,549 --> 01:03:56,960
non-heritable non-genetic memory and we

1854
01:04:00,549 --> 01:03:58,559
are studying this within the framework

1855
01:04:02,069 --> 01:04:00,559
of chemical evolution although the

1856
01:04:03,430 --> 01:04:02,079
global um

1857
01:04:05,870 --> 01:04:03,440
we're starting this within the framework

1858
01:04:07,990 --> 01:04:05,880
of pre-darwinism of

1859
01:04:09,109 --> 01:04:08,000
pre-pre-darwinism which is non-genetic

1860
01:04:09,910 --> 01:04:09,119
memory

1861
01:04:11,430 --> 01:04:09,920
um

1862
01:04:13,589 --> 01:04:11,440
i wouldn't go into i'm not going to go

1863
01:04:15,910 --> 01:04:13,599

into too much details right now but i

1864
01:04:18,150 --> 01:04:15,920
just wanted to give an outline of some

1865
01:04:19,510 --> 01:04:18,160
of the ideas in lab today and

1866
01:04:21,990 --> 01:04:19,520
they are

1867
01:04:24,150 --> 01:04:22,000
essentially when you cycle a group of

1868
01:04:26,950 --> 01:04:24,160
small molecules in a wet dry cycling

1869
01:04:29,430 --> 01:04:26,960
phenomena they show the capability of

1870
01:04:32,069 --> 01:04:29,440
recording environmental events like this

1871
01:04:34,230 --> 01:04:32,079
one here so when we cycle these group of

1872
01:04:36,789 --> 01:04:34,240
molecules in two different conditions

1873
01:04:38,710 --> 01:04:36,799
uh this specific environmental event was

1874
01:04:41,430 --> 01:04:38,720
recorded in the

1875
01:04:43,829 --> 01:04:41,440
hplc spectra of this memory now this is

1876
01:04:45,430 --> 01:04:43,839
independent of the individual molecules

1877
01:04:48,309 --> 01:04:45,440
independent of

1878
01:04:49,990 --> 01:04:48,319
the identity of these molecules this

1879
01:04:52,390 --> 01:04:50,000
recording is

1880
01:04:54,549 --> 01:04:52,400
not dependent on the specific structures

1881
01:04:55,829 --> 01:04:54,559
but this is an emergent phenomena i

1882
01:04:58,069 --> 01:04:55,839
think this is something really

1883
01:04:58,950 --> 01:04:58,079
interesting to know and i think this

1884
01:05:01,270 --> 01:04:58,960
should

1885
01:05:02,630 --> 01:05:01,280
inform future research into the origin

1886
01:05:06,870 --> 01:05:02,640
of life

1887
01:05:14,390 --> 01:05:10,300
finish my presentation um thank you

1888
01:05:16,230 --> 01:05:14,400

[Applause]

1889
01:05:18,150 --> 01:05:16,240
great thank you um do we have any

1890
01:05:22,789 --> 01:05:18,160
questions from the audience

1891
01:05:27,270 --> 01:05:24,950
thank you kavitha that was a great talk

1892
01:05:29,190 --> 01:05:27,280
could you go back one slide okay so yes

1893
01:05:31,190 --> 01:05:29,200
could you just explain a bit more about

1894
01:05:33,510 --> 01:05:31,200
how you're recording the environmental

1895
01:05:34,630 --> 01:05:33,520
events absolutely yeah

1896
01:05:36,470 --> 01:05:34,640
um

1897
01:05:37,990 --> 01:05:36,480
so the chemical system

1898
01:05:40,230 --> 01:05:38,000
we are exploring right now is

1899
01:05:42,630 --> 01:05:40,240
essentially a chemical evolution of

1900
01:05:43,829 --> 01:05:42,640
these eight of these eight different

1901
01:05:45,910 --> 01:05:43,839
components

1902
01:05:48,549 --> 01:05:45,920
uh where we wet dry cycle these eight

1903
01:05:51,589 --> 01:05:48,559
components and study the formation of a

1904
01:05:52,549 --> 01:05:51,599
wet these eight components at 45 degrees

1905
01:05:55,349 --> 01:05:52,559
and

1906
01:05:56,870 --> 01:05:55,359
studied the formation of polymers ah

1907
01:05:58,870 --> 01:05:56,880
through different analytical techniques

1908
01:06:00,950 --> 01:05:58,880
one of which is hplc

1909
01:06:03,430 --> 01:06:00,960
uh which is essentially

1910
01:06:05,109 --> 01:06:03,440
this graph writer is an absorbance at

1911
01:06:06,549 --> 01:06:05,119
210 nanometers

1912
01:06:07,750 --> 01:06:06,559
of the different

1913
01:06:09,270 --> 01:06:07,760

cycles

1914
01:06:13,029 --> 01:06:09,280
of

1915
01:06:14,710 --> 01:06:13,039
different cycles now when the same

1916
01:06:16,710 --> 01:06:14,720
system was run in two different

1917
01:06:19,349 --> 01:06:16,720
conditions one of which had a

1918
01:06:21,270 --> 01:06:19,359
perturbation slight perturbation at one

1919
01:06:22,309 --> 01:06:21,280
specific cycle and everything else was

1920
01:06:24,309 --> 01:06:22,319
the same

1921
01:06:27,829 --> 01:06:24,319
we recorded that when we compared the

1922
01:06:28,950 --> 01:06:27,839
spectra we had a significant um i guess

1923
01:06:31,670 --> 01:06:28,960
significant

1924
01:06:33,829 --> 01:06:31,680
perturbation in the hplc and this

1925
01:06:36,470 --> 01:06:33,839
perturbation faded over time so when we

1926
01:06:38,309 --> 01:06:36,480
ran this for maybe 15 or 20 cycles

1927
01:06:42,230 --> 01:06:38,319
the spectra then there was no difference

1928
01:06:43,750 --> 01:06:42,240
between the control and the um

1929
01:06:46,150 --> 01:06:43,760
perturb system

1930
01:06:48,630 --> 01:06:46,160
so this is something really really

1931
01:06:51,349 --> 01:06:48,640
interesting and i think this is actually

1932
01:06:56,710 --> 01:06:51,359
a path dependent

1933
01:07:01,349 --> 01:06:59,109
very cool and we do have a question from

1934
01:07:04,230 --> 01:07:01,359
blue jeans which is

1935
01:07:06,230 --> 01:07:04,240
do we also understand how new memory is

1936
01:07:08,789 --> 01:07:06,240
attached to nucleotides when there is

1937
01:07:12,150 --> 01:07:08,799
evolution in organisms are there any

1938
01:07:13,430 --> 01:07:12,160

specific chemicals involved

1939
01:07:14,950 --> 01:07:13,440
um

1940
01:07:16,549 --> 01:07:14,960
i am

1941
01:07:18,150 --> 01:07:16,559
not too sure

1942
01:07:22,710 --> 01:07:18,160
um

1943
01:07:24,870 --> 01:07:22,720
i would imagine that

1944
01:07:27,109 --> 01:07:24,880
um i guess creativity in the structure

1945
01:07:28,390 --> 01:07:27,119
of nucleic acids today would be very

1946
01:07:29,910 --> 01:07:28,400
difficult

1947
01:07:32,870 --> 01:07:29,920
um

1948
01:07:35,430 --> 01:07:32,880
but maybe without the framework of life

1949
01:07:37,510 --> 01:07:35,440
there may have been many more

1950
01:07:39,670 --> 01:07:37,520
chemical groups attached functional

1951
01:07:42,150 --> 01:07:39,680
groups attached and much more creativity

1952
01:07:43,910 --> 01:07:42,160
that's for sure

1953
01:07:45,109 --> 01:07:43,920
agreed thank you

1954
01:07:56,630 --> 01:07:45,119
um

1955
01:08:03,109 --> 01:08:00,390
i'm uh also curious about this uh

1956
01:08:05,589 --> 01:08:03,119
last little experiment that you are uh

1957
01:08:06,950 --> 01:08:05,599
talking about where you see uh

1958
01:08:08,630 --> 01:08:06,960
persistent

1959
01:08:09,589 --> 01:08:08,640
effects from perturbations that stick

1960
01:08:10,630 --> 01:08:09,599
around

1961
01:08:14,150 --> 01:08:10,640
um

1962
01:08:15,430 --> 01:08:14,160
i'm just looking at the graphs there and

1963
01:08:17,070 --> 01:08:15,440

um

1964
01:08:18,789 --> 01:08:17,080
is am i am i

1965
01:08:21,269 --> 01:08:18,799
interpreting

1966
01:08:22,870 --> 01:08:21,279
uh what the peaks mean

1967
01:08:24,309 --> 01:08:22,880
that when there are

1968
01:08:27,349 --> 01:08:24,319
peaks somewhere it means that there is

1969
01:08:29,829 --> 01:08:27,359
some kind of a substance that has uh

1970
01:08:31,030 --> 01:08:29,839
come together from the smaller pieces

1971
01:08:32,309 --> 01:08:31,040
and

1972
01:08:35,030 --> 01:08:32,319
if so

1973
01:08:36,630 --> 01:08:35,040
is there sort of like is it sort of like

1974
01:08:39,110 --> 01:08:36,640
not much is happening not not much is

1975
01:08:41,030 --> 01:08:39,120
happening then suddenly a bunch happens

1976
01:08:43,910 --> 01:08:41,040
and then it sticks around from that

1977
01:08:45,590 --> 01:08:43,920
point forward in the simplest terms yes

1978
01:08:47,990 --> 01:08:45,600
okay uh since this is a different

1979
01:08:49,990 --> 01:08:48,000
spectra right i have a sense different

1980
01:08:52,229 --> 01:08:50,000
spectrum okay i missed that so this is

1981
01:08:54,870 --> 01:08:52,239
the differentiation of uh i mean i've

1982
01:08:56,709 --> 01:08:54,880
subtracted uh one from the other but if

1983
01:08:58,550 --> 01:08:56,719
this was this this wasn't a different

1984
01:09:00,229 --> 01:08:58,560
spectra yes an individual peak would

1985
01:09:02,950 --> 01:09:00,239
mean a bunch of quality okay i missed

1986
01:09:04,630 --> 01:09:02,960
that part that's fine yeah so so okay so

1987
01:09:06,870 --> 01:09:04,640
the uh

1988
01:09:10,800 --> 01:09:06,880

okay that makes that makes sense um all

1989
01:09:15,030 --> 01:09:11,910
[Music]

1990
01:09:20,149 --> 01:09:17,189
can you go back to your uh i think you

1991
01:09:22,550 --> 01:09:20,159
had an original or a life definition or

1992
01:09:26,070 --> 01:09:22,560
something up there um

1993
01:09:31,510 --> 01:09:28,390
okay so it's like

1994
01:09:34,470 --> 01:09:31,520
life is um

1995
01:09:35,430 --> 01:09:34,480
sophisticated molecular memory right um

1996
01:09:37,749 --> 01:09:35,440
from that

1997
01:09:39,910 --> 01:09:37,759
so you gave the example of like prions

1998
01:09:42,070 --> 01:09:39,920
as a good um yes example of like what

1999
01:09:49,110 --> 01:09:42,080
you kind of like are thinking about so

2000
01:09:53,349 --> 01:09:51,030
i'm mostly just kidding with that that's

2001
01:09:57,990 --> 01:09:55,430
but yeah it's a cool idea

2002
01:10:01,590 --> 01:09:59,510
absolutely i think prions are really

2003
01:10:03,750 --> 01:10:01,600
interesting in

2004
01:10:05,270 --> 01:10:03,760
their structure and in recording events

2005
01:10:06,709 --> 01:10:05,280
independent of their sequence i think

2006
01:10:11,350 --> 01:10:06,719
that was something

2007
01:10:16,390 --> 01:10:14,149
uh this is a great talk thank you um

2008
01:10:18,550 --> 01:10:16,400
i was just curious how long do they do

2009
01:10:21,350 --> 01:10:18,560
you run the experiments for like how

2010
01:10:22,790 --> 01:10:21,360
much time is being captured

2011
01:10:24,470 --> 01:10:22,800
in these factories

2012
01:10:26,709 --> 01:10:24,480
yeah the cycles um

2013
01:10:29,030 --> 01:10:26,719

at this stage we only have up to cycle

2014
01:10:31,350 --> 01:10:29,040
15 for this specific experiment but we

2015
01:10:33,669 --> 01:10:31,360
definitely plan on doing longer cycles

2016
01:10:35,590 --> 01:10:33,679
set up in lab right now

2017
01:10:38,070 --> 01:10:35,600
but how much time oh i see i just

2018
01:10:40,229 --> 01:10:38,080
couldn't see from like

2019
01:10:43,590 --> 01:10:40,239
yeah how much time per cycle oh sorry

2020
01:10:44,470 --> 01:10:43,600
it's uh two days per cycle at 45 degrees

2021
01:10:48,709 --> 01:10:44,480
okay

2022
01:10:51,030 --> 01:10:48,719
and i'm assuming you're interested in

2023
01:10:53,350 --> 01:10:51,040
expanding the experiments

2024
01:10:55,030 --> 01:10:53,360
absolutely we have a grad student who's

2025
01:10:57,669 --> 01:10:55,040
working in our lab who's planning on

2026
01:11:00,070 --> 01:10:57,679
extending this phenomena much further as

2027
01:11:03,110 --> 01:11:00,080
well as looking at other emergent

2028
01:11:06,630 --> 01:11:03,120
properties of the system

2029
01:11:09,710 --> 01:11:07,910
thank you so we have to move on to the

2030
01:11:31,270 --> 01:11:09,720
next section but thank you

2031
01:11:35,030 --> 01:11:33,270
great our next speaker is jay haynes

2032
01:11:41,910 --> 01:11:35,040
presenting on experimental predictions

2033
01:11:46,229 --> 01:11:44,149
all right so uh as you noted my name is

2034
01:11:48,229 --> 01:11:46,239
jay i'm from uh the williams lab here at

2035
01:11:50,300 --> 01:11:48,239
georgia tech and so i'm gonna be talking

2036
01:11:52,070 --> 01:11:50,310
about ribosomal evolution today

2037
01:11:52,830 --> 01:11:52,080
[Music]

2038
01:11:55,430 --> 01:11:52,840

okay

2039
01:11:57,510 --> 01:11:55,440
so um in the williams lab we like to

2040
01:12:00,229 --> 01:11:57,520
talk or we like to do research on

2041
01:12:03,110 --> 01:12:00,239
translation the ribosome because these

2042
01:12:07,030 --> 01:12:03,120
processes are universal all life depends

2043
01:12:08,790 --> 01:12:07,040
on coded protein in order to um to do

2044
01:12:10,470 --> 01:12:08,800
its life cycle

2045
01:12:13,030 --> 01:12:10,480
and so um

2046
01:12:14,870 --> 01:12:13,040
the the process for creating coded

2047
01:12:17,910 --> 01:12:14,880
protein is um

2048
01:12:19,270 --> 01:12:17,920
is translation where we go from rna to

2049
01:12:21,590 --> 01:12:19,280
our um

2050
01:12:22,550 --> 01:12:21,600
protein that does the work in the in the

2051
01:12:25,350 --> 01:12:22,560
cell

2052
01:12:26,709 --> 01:12:25,360
and at the center of translation is the

2053
01:12:28,470 --> 01:12:26,719
ribosome

2054
01:12:29,590 --> 01:12:28,480
so it's like the nexus that collects

2055
01:12:30,950 --> 01:12:29,600
everything together that gets

2056
01:12:33,350 --> 01:12:30,960
translation done

2057
01:12:35,350 --> 01:12:33,360
so it's the focal point of of this

2058
01:12:37,189 --> 01:12:35,360
incredibly important life process and so

2059
01:12:38,390 --> 01:12:37,199
not only is translation the ribosome

2060
01:12:39,510 --> 01:12:38,400
universal

2061
01:12:42,390 --> 01:12:39,520
it's also

2062
01:12:44,390 --> 01:12:42,400
central and necessary for life so what

2063
01:12:46,790 --> 01:12:44,400

this means in terms of

2064
01:12:49,430 --> 01:12:46,800
evolution of the ribosome is that it's a

2065
01:12:51,110 --> 01:12:49,440
process that began at the very root of

2066
01:12:54,709 --> 01:12:51,120
the origin of life

2067
01:12:57,510 --> 01:12:54,719
so it's older than life as we know it

2068
01:12:59,590 --> 01:12:57,520
so using this insight our lab has

2069
01:13:01,830 --> 01:12:59,600
created a model for the evolution of the

2070
01:13:03,430 --> 01:13:01,840
ribosome called the accretion model

2071
01:13:05,590 --> 01:13:03,440
so that's this figure you see on the

2072
01:13:07,189 --> 01:13:05,600
right of this slide right here

2073
01:13:09,189 --> 01:13:07,199
so as i mentioned earlier this is a

2074
01:13:10,390 --> 01:13:09,199
process that started before exiting bio

2075
01:13:13,270 --> 01:13:10,400
biology

2076
01:13:15,270 --> 01:13:13,280
so um you know the beginnings of it was

2077
01:13:17,510 --> 01:13:15,280
billions of years ago and this is a

2078
01:13:19,189 --> 01:13:17,520
process that if we continue up this kind

2079
01:13:22,070 --> 01:13:19,199
of model

2080
01:13:24,709 --> 01:13:22,080
uh um timeline you know at the very end

2081
01:13:26,630 --> 01:13:24,719
here this is still an ongoing process so

2082
01:13:27,990 --> 01:13:26,640
it's a process that spans multi-billion

2083
01:13:29,669 --> 01:13:28,000
years

2084
01:13:31,189 --> 01:13:29,679
but for the purposes today i'm just

2085
01:13:33,430 --> 01:13:31,199
gonna be talking about

2086
01:13:35,830 --> 01:13:33,440
a a smaller portion of that

2087
01:13:38,310 --> 01:13:35,840
multi-billion years that focuses on

2088
01:13:40,870 --> 01:13:38,320

ribosomal structure

2089
01:13:43,350 --> 01:13:40,880
and so uh the kind of the the basic idea

2090
01:13:45,189 --> 01:13:43,360
of the accretion model is that uh

2091
01:13:46,550 --> 01:13:45,199
evolutionary process

2092
01:13:48,790 --> 01:13:46,560
um

2093
01:13:50,870 --> 01:13:48,800
is is based on this idea of building on

2094
01:13:52,229 --> 01:13:50,880
top of things that came before and so

2095
01:13:54,950 --> 01:13:52,239
specifically what i'll be talking about

2096
01:13:56,709 --> 01:13:54,960
today is the early early ribosome growth

2097
01:13:59,350 --> 01:13:56,719
and evolution that happens through

2098
01:14:01,430 --> 01:13:59,360
accretion of structural elements and so

2099
01:14:03,189 --> 01:14:01,440
um whenever i'm talking about structural

2100
01:14:05,270 --> 01:14:03,199
elements specifically what i'm

2101
01:14:08,149 --> 01:14:05,280
referencing is what i'll be referencing

2102
01:14:09,669 --> 01:14:08,159
is rna structural elements and i'll be

2103
01:14:11,669 --> 01:14:09,679
um

2104
01:14:13,350 --> 01:14:11,679
calling those rna structural elements

2105
01:14:14,550 --> 01:14:13,360
specifically ancestral expansion

2106
01:14:15,669 --> 01:14:14,560
segments

2107
01:14:17,750 --> 01:14:15,679
and so

2108
01:14:19,910 --> 01:14:17,760
as i said the idea is that

2109
01:14:21,990 --> 01:14:19,920
accretion is this process by which we

2110
01:14:25,030 --> 01:14:22,000
don't perturb a structure that came

2111
01:14:28,550 --> 01:14:25,040
before and we build upon and elaborate

2112
01:14:31,030 --> 01:14:28,560
more structure on top of that

2113
01:14:33,030 --> 01:14:31,040

so i've just um i just kind of briefly

2114
01:14:34,149 --> 01:14:33,040
uh introduced our model for ribosomal

2115
01:14:37,430 --> 01:14:34,159
evolution

2116
01:14:40,310 --> 01:14:37,440
so my goal today will be to characterize

2117
01:14:42,390 --> 01:14:40,320
what is the first five um aes or

2118
01:14:44,870 --> 01:14:42,400
ancestral expansion segments

2119
01:14:47,030 --> 01:14:44,880
within the accretion model

2120
01:14:48,870 --> 01:14:47,040
so in terms of experimental system uh

2121
01:14:51,189 --> 01:14:48,880
that translates into

2122
01:14:53,669 --> 01:14:51,199
six rnas that are some subset of the

2123
01:14:56,470 --> 01:14:53,679
first five ancestral expansion segments

2124
01:14:57,830 --> 01:14:56,480
which i have i've listed those rnas here

2125
01:14:59,189 --> 01:14:57,840
and so if we look at this figure on the

2126
01:15:00,470 --> 01:14:59,199
right

2127
01:15:01,830 --> 01:15:00,480
we can see

2128
01:15:14,950 --> 01:15:01,840
the

2129
01:15:17,830 --> 01:15:14,960
whereby aes2

2130
01:15:20,950 --> 01:15:17,840
creates on aes1 and so we can see in red

2131
01:15:22,149 --> 01:15:20,960
this helical structure here is aes1

2132
01:15:24,709 --> 01:15:22,159
and then

2133
01:15:26,470 --> 01:15:24,719
we have the accretion of aes2 on as1 and

2134
01:15:28,470 --> 01:15:26,480
as i mentioned earlier feature of this

2135
01:15:31,110 --> 01:15:28,480
process is that the underlying

2136
01:15:33,270 --> 01:15:31,120
pre-existing structure in this case aes1

2137
01:15:35,189 --> 01:15:33,280
is unperturbed even though we've kind of

2138
01:15:37,430 --> 01:15:35,199

added on this extra structure and then

2139
01:15:40,149 --> 01:15:37,440
we can see in other panels accretion of

2140
01:15:44,550 --> 01:15:40,159
aes3 on the as1

2141
01:15:47,669 --> 01:15:44,560
as4 creates onto as3 as5 on three

2142
01:15:49,350 --> 01:15:47,679
and then in this panel d we see um

2143
01:15:52,310 --> 01:15:49,360
secondary structure which this is just a

2144
01:15:55,750 --> 01:15:52,320
two-dimensional representation of um

2145
01:15:57,350 --> 01:15:55,760
structure of of rna that we'll sometimes

2146
01:15:58,870 --> 01:15:57,360
be using in lieu of the

2147
01:16:00,149 --> 01:15:58,880
three-dimensional structure and then

2148
01:16:02,310 --> 01:16:00,159
here on the bottom we have a

2149
01:16:04,149 --> 01:16:02,320
three-dimensional representation of all

2150
01:16:06,149 --> 01:16:04,159
five of the ancestral expansion segments

2151
01:16:07,830 --> 01:16:06,159
together

2152
01:16:11,350 --> 01:16:07,840
so

2153
01:16:12,550 --> 01:16:11,360
talking about today

2154
01:16:15,270 --> 01:16:12,560
i'll be

2155
01:16:16,870 --> 01:16:15,280
talking about uv melting experiments

2156
01:16:19,430 --> 01:16:16,880
so the basic idea of that is we're going

2157
01:16:21,430 --> 01:16:19,440
to monitor the absorbance

2158
01:16:23,350 --> 01:16:21,440
of our rna signal as we change the

2159
01:16:25,590 --> 01:16:23,360
temperature and that'll give us a

2160
01:16:26,950 --> 01:16:25,600
melting curve and then we'll take the

2161
01:16:29,189 --> 01:16:26,960
derivative of that melting curve and

2162
01:16:31,669 --> 01:16:29,199
we'll fit it to a model that'll let us

2163
01:16:33,189 --> 01:16:31,679

see the transitions occurring

2164
01:16:34,709 --> 01:16:33,199
within that rna and that we'll use that

2165
01:16:37,830 --> 01:16:34,719
as like a proxy for

2166
01:16:40,470 --> 01:16:37,840
viewing the structure within that rna

2167
01:16:42,229 --> 01:16:40,480
and then we'll also look at um

2168
01:16:43,669 --> 01:16:42,239
shape which is a

2169
01:16:46,470 --> 01:16:43,679
structure probing method which i'll go

2170
01:16:49,430 --> 01:16:46,480
into more detail later

2171
01:16:51,350 --> 01:16:49,440
so first i want to talk about uh melting

2172
01:16:53,030 --> 01:16:51,360
so i'll start off by saying that these

2173
01:16:54,790 --> 01:16:53,040
experiments and the figures you see on

2174
01:16:57,030 --> 01:16:54,800
the slide were done by a previous

2175
01:16:58,790 --> 01:16:57,040
student in the lab catherine lanier

2176
01:17:00,310 --> 01:16:58,800
and so um

2177
01:17:03,830 --> 01:17:00,320
so maybe first we'll start off by

2178
01:17:05,830 --> 01:17:03,840
looking at panel a here which this is um

2179
01:17:08,870 --> 01:17:05,840
we see the structure of aes1 in this

2180
01:17:11,430 --> 01:17:08,880
panel and then we also see in colored in

2181
01:17:13,430 --> 01:17:11,440
this kind of solid colored line we see

2182
01:17:16,390 --> 01:17:13,440
the um

2183
01:17:18,950 --> 01:17:16,400
the derivative of the melting curve of

2184
01:17:21,350 --> 01:17:18,960
aes1 and then in the dotted line and the

2185
01:17:23,270 --> 01:17:21,360
dotted line we see the fit of that curve

2186
01:17:25,350 --> 01:17:23,280
and then in the solid black lines we see

2187
01:17:26,470 --> 01:17:25,360
what we're really interested in which is

2188
01:17:28,709 --> 01:17:26,480

the um

2189
01:17:31,910 --> 01:17:28,719
individual transitions that make up that

2190
01:17:34,870 --> 01:17:31,920
fit so this is these are basically um

2191
01:17:37,510 --> 01:17:34,880
we're basically looking at um

2192
01:17:39,750 --> 01:17:37,520
you know the if we if we consider

2193
01:17:41,189 --> 01:17:39,760
of this of this profile this melting

2194
01:17:42,470 --> 01:17:41,199
profile looks like we have two major

2195
01:17:43,750 --> 01:17:42,480
transitions

2196
01:17:46,950 --> 01:17:43,760
where uh

2197
01:17:48,870 --> 01:17:46,960
we we suggested these two transitions uh

2198
01:17:51,510 --> 01:17:48,880
correspond to the two kind of helical

2199
01:17:52,630 --> 01:17:51,520
regions within as1 so as i mentioned

2200
01:17:55,110 --> 01:17:52,640
earlier we're kind of looking at these

2201
01:17:56,630 --> 01:17:55,120
transitions as a proxy for the structure

2202
01:17:58,550 --> 01:17:56,640
in these um

2203
01:18:00,310 --> 01:17:58,560
in these rna elements

2204
01:18:02,950 --> 01:18:00,320
and so our prediction based on the

2205
01:18:05,270 --> 01:18:02,960
accretion model is that um because we're

2206
01:18:07,110 --> 01:18:05,280
adding structure on top of structure we

2207
01:18:09,110 --> 01:18:07,120
should see new transitions appearing

2208
01:18:12,229 --> 01:18:09,120
with these accretion events and so for

2209
01:18:14,709 --> 01:18:12,239
example if we consider the aes1 profile

2210
01:18:17,270 --> 01:18:14,719
and then we look at aes 1 comma 3 which

2211
01:18:19,189 --> 01:18:17,280
is the accretion of 3 onto one we see

2212
01:18:20,790 --> 01:18:19,199
indeed that there is an extra transition

2213
01:18:22,950 --> 01:18:20,800

that appears so so here we have like

2214
01:18:24,310 --> 01:18:22,960
three major transitions a yes one we

2215
01:18:25,990 --> 01:18:24,320
only have two

2216
01:18:27,590 --> 01:18:26,000
so i'll go ahead and say that we see the

2217
01:18:29,590 --> 01:18:27,600
same trend

2218
01:18:32,310 --> 01:18:29,600
so the trim we saw we with the es3 we

2219
01:18:33,669 --> 01:18:32,320
see that with the creation of aes4 as

2220
01:18:34,870 --> 01:18:33,679
well down here

2221
01:18:36,630 --> 01:18:34,880
however

2222
01:18:41,430 --> 01:18:36,640
we don't really see this trend whenever

2223
01:18:43,270 --> 01:18:41,440
we create aes2 and then down here as5

2224
01:18:46,310 --> 01:18:43,280
and essentially what we think this boils

2225
01:18:47,990 --> 01:18:46,320
down to is the fact that as2 and 5 are

2226
01:18:50,630 --> 01:18:48,000
smaller structural elements they're only

2227
01:18:52,950 --> 01:18:50,640
about 20 nucleotides long and so

2228
01:18:54,550 --> 01:18:52,960
essentially what that means is that

2229
01:18:56,470 --> 01:18:54,560
those structures are small and so

2230
01:18:59,590 --> 01:18:56,480
whenever we melt them out we expect this

2231
01:19:03,110 --> 01:18:59,600
to have a very sharp um transition a

2232
01:19:06,310 --> 01:19:03,120
very very sharp kind of peak and so it's

2233
01:19:07,990 --> 01:19:06,320
likely that those peaks are being um

2234
01:19:10,229 --> 01:19:08,000
being covered up by the these larger

2235
01:19:12,950 --> 01:19:10,239
broader peaks that are associated with

2236
01:19:14,390 --> 01:19:12,960
um larger structural elements

2237
01:19:15,910 --> 01:19:14,400
so that's one part of the story and the

2238
01:19:18,550 --> 01:19:15,920

other part of the story

2239
01:19:21,189 --> 01:19:18,560
um that our model predicts is that we

2240
01:19:23,590 --> 01:19:21,199
shouldn't uh that the previous existing

2241
01:19:26,390 --> 01:19:23,600
transition shouldn't be perturbed at all

2242
01:19:27,910 --> 01:19:26,400
so um that's the prediction however uh

2243
01:19:29,669 --> 01:19:27,920
the picture that the data shows is much

2244
01:19:32,470 --> 01:19:29,679
more complicated so once again if we

2245
01:19:35,750 --> 01:19:32,480
focus on as1 we see we have two kind of

2246
01:19:37,990 --> 01:19:35,760
major transitions here one at around 7dc

2247
01:19:39,350 --> 01:19:38,000
and one at around 60 c

2248
01:19:41,030 --> 01:19:39,360
and then we see

2249
01:19:43,590 --> 01:19:41,040
if we once again compare with aes 1

2250
01:19:45,990 --> 01:19:43,600
comma 3 there's at least one transition

2251
01:19:48,390 --> 01:19:46,000
that looks like it's been shifted

2252
01:19:51,669 --> 01:19:48,400
and we see this trend in all of the

2253
01:19:54,229 --> 01:19:51,679
melting profiles where there's um

2254
01:19:57,030 --> 01:19:54,239
a um a peak that's shifted in terms of

2255
01:19:59,350 --> 01:19:57,040
its temperature range or um the the peak

2256
01:20:01,510 --> 01:19:59,360
is broadened so um

2257
01:20:04,310 --> 01:20:01,520
some kind of you know changes

2258
01:20:05,830 --> 01:20:04,320
to uh to the transitions happening so on

2259
01:20:07,189 --> 01:20:05,840
the one hand this seems to suggest that

2260
01:20:09,830 --> 01:20:07,199
maybe there's disagreement with our

2261
01:20:12,070 --> 01:20:09,840
model but however if we

2262
01:20:14,550 --> 01:20:12,080
if we consider the structure of the

2263
01:20:15,830 --> 01:20:14,560

ribosome that corresponds to aes one

2264
01:20:17,510 --> 01:20:15,840
through five

2265
01:20:18,709 --> 01:20:17,520
and we map on the base pairing

2266
01:20:21,510 --> 01:20:18,719
interactions of that region of the

2267
01:20:24,310 --> 01:20:21,520
ribosome as as we see in the magenta

2268
01:20:26,310 --> 01:20:24,320
lines here in this figure on the left

2269
01:20:28,310 --> 01:20:26,320
what we see is that this region of the

2270
01:20:30,070 --> 01:20:28,320
ribosome is actually really

2271
01:20:31,669 --> 01:20:30,080
these nucleotides are really integrated

2272
01:20:34,390 --> 01:20:31,679
in terms of their base pairing

2273
01:20:36,470 --> 01:20:34,400
interactions and so while the overall

2274
01:20:39,270 --> 01:20:36,480
structure may not be perturbed whenever

2275
01:20:40,390 --> 01:20:39,280
we um accrete a structural element

2276
01:20:42,149 --> 01:20:40,400
um

2277
01:20:44,390 --> 01:20:42,159
we're still kind of

2278
01:20:46,390 --> 01:20:44,400
changing this um the overall molecule in

2279
01:20:48,310 --> 01:20:46,400
the sense that we're adding um base

2280
01:20:49,830 --> 01:20:48,320
pairing interactions and so what that

2281
01:20:51,110 --> 01:20:49,840
ends up doing is changing the

2282
01:20:52,470 --> 01:20:51,120
thermodynamic properties of these

2283
01:20:54,149 --> 01:20:52,480
structures and so while the

2284
01:20:57,270 --> 01:20:54,159
three-dimensional conformation might not

2285
01:20:59,030 --> 01:20:57,280
be changing we are perturbing the um

2286
01:21:00,149 --> 01:20:59,040
the transitions to the thermodynamic

2287
01:21:03,350 --> 01:21:00,159
properties and so that's why we're

2288
01:21:04,790 --> 01:21:03,360

seeing shifting and broadening here

2289
01:21:07,270 --> 01:21:04,800
so we still so we think that that still

2290
01:21:08,629 --> 01:21:07,280
agrees with our model um

2291
01:21:10,950 --> 01:21:08,639
okay so the last thing i want to talk

2292
01:21:12,790 --> 01:21:10,960
about is shape and so the basic idea of

2293
01:21:15,990 --> 01:21:12,800
a shape experiment is that

2294
01:21:17,910 --> 01:21:16,000
you have structured rna you add your a

2295
01:21:20,870 --> 01:21:17,920
reagent and specifically this reagent

2296
01:21:22,709 --> 01:21:20,880
will selectively modify nucleotides that

2297
01:21:24,070 --> 01:21:22,719
are not base paired

2298
01:21:25,270 --> 01:21:24,080
and then we do reverse transcription

2299
01:21:27,510 --> 01:21:25,280
reaction

2300
01:21:30,229 --> 01:21:27,520
and basically what ends up happening is

2301
01:21:32,709 --> 01:21:30,239
wherever there's a modification the rt

2302
01:21:34,149 --> 01:21:32,719
likes to stop and that creates fragments

2303
01:21:36,229 --> 01:21:34,159
and then we can analyze those fragments

2304
01:21:37,990 --> 01:21:36,239
to get an idea of which nucleotides

2305
01:21:41,590 --> 01:21:38,000
within our rna tend to be modified and

2306
01:21:42,390 --> 01:21:41,600
therefore tend to be not base pairing

2307
01:21:44,070 --> 01:21:42,400
and so

2308
01:21:45,669 --> 01:21:44,080
okay so this is like a this is like the

2309
01:21:47,910 --> 01:21:45,679
broad kind of global

2310
01:21:50,310 --> 01:21:47,920
um perspective of the shape data i've

2311
01:21:53,189 --> 01:21:50,320
collected and there's a lot here and so

2312
01:21:55,510 --> 01:21:53,199
for the for sake of brevity and clarity

2313
01:21:58,070 --> 01:21:55,520

i'm going to kind of just focus on one

2314
01:21:59,990 --> 01:21:58,080
region to kind of illustrate

2315
01:22:01,030 --> 01:22:00,000
comparisons

2316
01:22:03,990 --> 01:22:01,040
and so

2317
01:22:08,229 --> 01:22:05,669
we see the shape profile of aes one

2318
01:22:09,750 --> 01:22:08,239
through five so

2319
01:22:12,390 --> 01:22:09,760
this may look like a jumble of circles

2320
01:22:14,470 --> 01:22:12,400
and colors but uh the idea is that this

2321
01:22:16,390 --> 01:22:14,480
is the secondary structure of aes one

2322
01:22:18,870 --> 01:22:16,400
through five and essentially what we've

2323
01:22:21,750 --> 01:22:18,880
done is we've made each nucleotide a

2324
01:22:22,629 --> 01:22:21,760
little circle and uh each circle has a

2325
01:22:26,950 --> 01:22:22,639
color

2326
01:22:29,030 --> 01:22:26,960
denotes a shape reactivity so it's it's

2327
01:22:31,030 --> 01:22:29,040
telling us what's the likelihood of that

2328
01:22:32,709 --> 01:22:31,040
nucleotide for forming base pairing

2329
01:22:35,350 --> 01:22:32,719
interactions

2330
01:22:36,950 --> 01:22:35,360
and so we see like really dark colored

2331
01:22:38,870 --> 01:22:36,960
dark blue and that's like low to no

2332
01:22:41,830 --> 01:22:38,880
shape reactivity and then as we move to

2333
01:22:44,470 --> 01:22:41,840
warmer colors like you can see a

2334
01:22:45,590 --> 01:22:44,480
light blue there to like a green to like

2335
01:22:48,149 --> 01:22:45,600
a yellow

2336
01:22:50,709 --> 01:22:48,159
um we're increasing the reactivity of

2337
01:22:52,790 --> 01:22:50,719
our of our nucleotide

2338
01:22:54,629 --> 01:22:52,800

and so i kind of i've circled this

2339
01:22:56,229 --> 01:22:54,639
region of the structure and this is the

2340
01:22:58,310 --> 01:22:56,239
region of interest that i want to focus

2341
01:23:02,310 --> 01:22:58,320
on um so that it's a little easier to

2342
01:23:04,229 --> 01:23:02,320
see patterns and so um i've re-um so

2343
01:23:06,629 --> 01:23:04,239
i've kind of reproduced this region for

2344
01:23:08,149 --> 01:23:06,639
each of the six rnas that are in my kind

2345
01:23:09,110 --> 01:23:08,159
of experimental set over here to the

2346
01:23:10,310 --> 01:23:09,120
right

2347
01:23:12,709 --> 01:23:10,320
and

2348
01:23:14,470 --> 01:23:12,719
basically we see a trend whereby the

2349
01:23:16,470 --> 01:23:14,480
nucleotides in the region around

2350
01:23:18,709 --> 01:23:16,480
position 80 then have heightened

2351
01:23:21,110 --> 01:23:18,719
reactivity compared to

2352
01:23:23,990 --> 01:23:21,120
nucleotides in the surrounding region

2353
01:23:26,709 --> 01:23:24,000
and so we take this as a as indication

2354
01:23:28,550 --> 01:23:26,719
that you know our experimental set is

2355
01:23:30,629 --> 01:23:28,560
consistent in terms of its structure in

2356
01:23:32,830 --> 01:23:30,639
terms of space pairing but also what

2357
01:23:35,110 --> 01:23:32,840
we're interested in is whether or not

2358
01:23:36,149 --> 01:23:35,120
um whether or not there's agreement

2359
01:23:38,709 --> 01:23:36,159
between

2360
01:23:41,110 --> 01:23:38,719
these experimental is this is

2361
01:23:43,270 --> 01:23:41,120
sorry this experimental system and the

2362
01:23:44,629 --> 01:23:43,280
structure of the ribosome itself

2363
01:23:48,390 --> 01:23:44,639

and so

2364
01:23:49,990 --> 01:23:48,400
if we look at the corresponding region

2365
01:23:51,910 --> 01:23:50,000
of the ribosome the region that

2366
01:23:52,950 --> 01:23:51,920
corresponds to what we're looking to

2367
01:23:55,350 --> 01:23:52,960
over here

2368
01:23:56,950 --> 01:23:55,360
we we see that um you know once again

2369
01:23:59,510 --> 01:23:56,960
base pairing interactions in these with

2370
01:24:02,070 --> 01:23:59,520
these magenta lines we see that the

2371
01:24:03,990 --> 01:24:02,080
structure of the ribosome agrees and

2372
01:24:07,910 --> 01:24:04,000
that the region that corresponds to this

2373
01:24:09,669 --> 01:24:07,920
position 80 over here is is not forming

2374
01:24:11,750 --> 01:24:09,679
um any any kind of base pairing

2375
01:24:13,270 --> 01:24:11,760
interactions so we see not only does our

2376
01:24:16,149 --> 01:24:13,280
experimental system agree with itself

2377
01:24:18,149 --> 01:24:16,159
but it also looks to agree with um the

2378
01:24:21,590 --> 01:24:18,159
base pairing as we expect it from the

2379
01:24:25,669 --> 01:24:23,910
okay so so with that i kind of i want to

2380
01:24:27,510 --> 01:24:25,679
conclude and just go ahead and say

2381
01:24:29,669 --> 01:24:27,520
broadly we think that the data that

2382
01:24:32,390 --> 01:24:29,679
we're collecting

2383
01:24:34,950 --> 01:24:32,400
agrees with our model for um

2384
01:24:37,350 --> 01:24:34,960
accretion um um

2385
01:24:40,310 --> 01:24:37,360
evolution evolution by accretion for the

2386
01:24:42,229 --> 01:24:40,320
ribosome and um it seems like we've been

2387
01:24:44,709 --> 01:24:42,239
able to resurrect some really ancient

2388
01:24:46,629 --> 01:24:44,719

truly ancient rna fragments and even

2389
01:24:48,470 --> 01:24:46,639
more broadly we've shown that we can use

2390
01:24:50,870 --> 01:24:48,480
some biophysical approaches to help us

2391
01:24:53,030 --> 01:24:50,880
answer some really um really deep uh

2392
01:24:54,870 --> 01:24:53,040
evolutionary questions

2393
01:24:56,870 --> 01:24:54,880
uh and so with that

2394
01:24:59,270 --> 01:24:56,880
i will say thanks for listening

2395
01:25:01,669 --> 01:24:59,280
um i'd like to give credit to of course

2396
01:25:03,750 --> 01:25:01,679
my advisor lauren williams for

2397
01:25:07,030 --> 01:25:03,760
um helping me out with this project

2398
01:25:08,470 --> 01:25:07,040
um anton petrov who's a

2399
01:25:09,990 --> 01:25:08,480
research scientist in our group did a

2400
01:25:11,510 --> 01:25:10,000
lot of like the foundational work that

2401
01:25:13,030 --> 01:25:11,520
led to this

2402
01:25:14,709 --> 01:25:13,040
this work and then as i mentioned

2403
01:25:17,270 --> 01:25:14,719
earlier catherine lear also made

2404
01:25:19,030 --> 01:25:17,280
contributions and then i'd also like to

2405
01:25:21,430 --> 01:25:19,040
recognize support from nasa in the form

2406
01:25:22,550 --> 01:25:21,440
of the center for chemical evolution

2407
01:25:23,990 --> 01:25:22,560
down here and then the center for the

2408
01:25:26,060 --> 01:25:24,000
origin of life

2409
01:25:30,550 --> 01:25:26,070
and i'll be happy to take any questions

2410
01:25:30,560 --> 01:25:39,030
great do we have any questions

2411
01:25:42,070 --> 01:25:40,629
all right so

2412
01:25:43,910 --> 01:25:42,080
there so

2413
01:25:44,870 --> 01:25:43,920

even just in

2414
01:25:46,070 --> 01:25:44,880
this

2415
01:25:48,310 --> 01:25:46,080
sort of

2416
01:25:51,910 --> 01:25:48,320
limited thing you've got uh you've this

2417
01:25:53,590 --> 01:25:51,920
limited region you've got a couple of

2418
01:25:54,790 --> 01:25:53,600
uh segments

2419
01:26:00,070 --> 01:25:54,800
and

2420
01:26:02,390 --> 01:26:00,080
with just five which i think was the

2421
01:26:05,669 --> 01:26:02,400
number you had you start getting crazy

2422
01:26:08,629 --> 01:26:05,679
combinatorics about which ones could uh

2423
01:26:10,310 --> 01:26:08,639
which ones you could

2424
01:26:12,629 --> 01:26:10,320
put together

2425
01:26:15,910 --> 01:26:12,639
part one is there a reason for choosing

2426
01:26:17,030 --> 01:26:15,920
exactly which sets that you chose and

2427
01:26:20,070 --> 01:26:17,040
part two

2428
01:26:22,470 --> 01:26:20,080
is it possible that by looking at

2429
01:26:24,229 --> 01:26:22,480
which editions produce the smallest

2430
01:26:27,270 --> 01:26:24,239
changes when they're added might that

2431
01:26:29,590 --> 01:26:27,280
have relevance to which additions

2432
01:26:30,950 --> 01:26:29,600
actually occurred in what order in

2433
01:26:33,110 --> 01:26:30,960
actual history

2434
01:26:34,550 --> 01:26:33,120
that's a great question so

2435
01:26:36,550 --> 01:26:34,560
um

2436
01:26:39,110 --> 01:26:36,560
i i kind of wish i had time to talk

2437
01:26:41,430 --> 01:26:39,120
about this i i cut i cut out some of the

2438
01:26:42,470 --> 01:26:41,440

background just for the sake of time but

2439
01:26:43,910 --> 01:26:42,480
um

2440
01:26:45,990 --> 01:26:43,920
you know all the details surrounding

2441
01:26:48,470 --> 01:26:46,000
that is is kind of built into the model

2442
01:26:49,430 --> 01:26:48,480
but the basic idea is that

2443
01:26:52,229 --> 01:26:49,440
um

2444
01:26:54,950 --> 01:26:52,239
you know the reason we were approaching

2445
01:26:56,470 --> 01:26:54,960
this accretion idea of the evolution of

2446
01:26:58,870 --> 01:26:56,480
the ribosome is because if you look at

2447
01:27:01,510 --> 01:26:58,880
extant ribosomes um they're not all the

2448
01:27:03,350 --> 01:27:01,520
same so like human ribosomes and e coli

2449
01:27:06,390 --> 01:27:03,360
ribosomes our ribosomes are actually

2450
01:27:08,310 --> 01:27:06,400
larger in terms of their ribosomal rna

2451
01:27:10,310 --> 01:27:08,320
there's an increase in size and so

2452
01:27:11,189 --> 01:27:10,320
basically what people have seen is that

2453
01:27:12,629 --> 01:27:11,199
um

2454
01:27:14,550 --> 01:27:12,639
you know even if you look at extant

2455
01:27:16,550 --> 01:27:14,560
ribosomes we can kind of see this

2456
01:27:18,550 --> 01:27:16,560
process whereby

2457
01:27:20,790 --> 01:27:18,560
you know new regions are added on to old

2458
01:27:22,870 --> 01:27:20,800
regions and you can actually tell

2459
01:27:26,310 --> 01:27:22,880
that certain regions came before others

2460
01:27:27,510 --> 01:27:26,320
because as in as as we look at this um

2461
01:27:28,550 --> 01:27:27,520
this slide

2462
01:27:34,870 --> 01:27:28,560
um

2463
01:27:35,910 --> 01:27:34,880

interactions are within the ribosome

2464
01:27:37,750 --> 01:27:35,920
there are

2465
01:27:39,590 --> 01:27:37,760
certain structures that had to exist

2466
01:27:42,229 --> 01:27:39,600
before others so like the the metaphor

2467
01:27:43,750 --> 01:27:42,239
is is to think of it like um you know if

2468
01:27:46,550 --> 01:27:43,760
you're looking at a tree

2469
01:27:47,430 --> 01:27:46,560
um you know it's it's it's very obvious

2470
01:27:49,750 --> 01:27:47,440
that

2471
01:27:51,510 --> 01:27:49,760
the branch the branch off the trunk

2472
01:27:54,390 --> 01:27:51,520
clearly grew out of the trunk and it had

2473
01:27:56,550 --> 01:27:54,400
to have existed after the trunk and so

2474
01:27:58,709 --> 01:27:56,560
we kind of use that mentality of this

2475
01:28:01,350 --> 01:27:58,719
kind of dependency of structure and

2476
01:28:03,270 --> 01:28:01,360
that's that's the whole basis of of the

2477
01:28:05,669 --> 01:28:03,280
numbering of these ancestral expansion

2478
01:28:07,430 --> 01:28:05,679
segments so it's all it's all structure

2479
01:28:10,310 --> 01:28:07,440
based and the

2480
01:28:13,669 --> 01:28:10,320
the ordering of the um

2481
01:28:14,709 --> 01:28:13,679
of the uh combinations is very dependent

2482
01:28:17,590 --> 01:28:14,719
on that

2483
01:28:36,950 --> 01:28:19,030
great thank you so we have to move on so

2484
01:28:36,960 --> 01:28:47,350
yes

2485
01:28:51,350 --> 01:28:49,110
all right our next speaker is brooke

2486
01:28:54,310 --> 01:28:51,360
rothschild mancinelli presenting on

2487
01:28:57,189 --> 01:28:54,320
using the scrvca mitochondrial ribosome

2488
01:28:58,870 --> 01:28:57,199

as an orthogonal evolve evolvable sorry

2489
01:29:00,870 --> 01:28:58,880
translation system

2490
01:29:03,430 --> 01:29:00,880
thank you

2491
01:29:05,669 --> 01:29:03,440
all right um as you said i'm brooke and

2492
01:29:08,070 --> 01:29:05,679
i'm here to round out the trio of

2493
01:29:10,149 --> 01:29:08,080
williams lab presentations

2494
01:29:11,750 --> 01:29:10,159
and jay just talked about the past

2495
01:29:13,750 --> 01:29:11,760
evolution of the ribosome i'll be

2496
01:29:15,430 --> 01:29:13,760
talking about taking the ribosome and

2497
01:29:17,270 --> 01:29:15,440
evolving it further

2498
01:29:19,270 --> 01:29:17,280
and to this i'll be using the

2499
01:29:21,590 --> 01:29:19,280
saccharomyces cerevisiae mitochondrial

2500
01:29:23,510 --> 01:29:21,600
ribosome as an orthogonal evolvable

2501
01:29:25,669 --> 01:29:23,520
translation system

2502
01:29:28,149 --> 01:29:25,679
so let's just start with the translation

2503
01:29:30,470 --> 01:29:28,159
system as jay briefly touched on it it

2504
01:29:34,709 --> 01:29:30,480
is a system of a lot of interconnected

2505
01:29:36,870 --> 01:29:34,719
parts you have mrna trna amino acid trna

2506
01:29:38,390 --> 01:29:36,880
transferases and at the core of it all

2507
01:29:39,189 --> 01:29:38,400
is the ribosome

2508
01:29:40,950 --> 01:29:39,199
um

2509
01:29:44,550 --> 01:29:40,960
and through billions of years of

2510
01:29:47,510 --> 01:29:44,560
evolution this ribosome has evolved to

2511
01:29:49,350 --> 01:29:47,520
take the alpha l amino acids make amide

2512
01:29:51,270 --> 01:29:49,360
bonds and we've got these peptides

2513
01:29:53,669 --> 01:29:51,280

proteins coming out of it

2514
01:29:55,990 --> 01:29:53,679
but at its core it's not just making

2515
01:29:57,990 --> 01:29:56,000
these ami bonds it is a polymerization

2516
01:29:59,830 --> 01:29:58,000
machine it's finely tuned in the way

2517
01:30:02,870 --> 01:29:59,840
life is right now but it is making

2518
01:30:05,030 --> 01:30:02,880
polymers um so that means it can be its

2519
01:30:07,430 --> 01:30:05,040
function can be extended expanded to

2520
01:30:09,510 --> 01:30:07,440
make other kinds of polymers and that's

2521
01:30:12,229 --> 01:30:09,520
actually a lot of interest when you use

2522
01:30:14,310 --> 01:30:12,239
like non-canonical amino acids um and

2523
01:30:16,550 --> 01:30:14,320
other things uh because it's so

2524
01:30:18,470 --> 01:30:16,560
efficient at this um the problem with

2525
01:30:20,870 --> 01:30:18,480
evolving the ribosome is that there's a

2526
01:30:22,709 --> 01:30:20,880
really large sequence design space we've

2527
01:30:25,189 --> 01:30:22,719
got the ribosomal proteins we have the

2528
01:30:28,070 --> 01:30:25,199
ribosomal rna it's just huge it's not

2529
01:30:31,030 --> 01:30:28,080
possible to do in vitro evolving of the

2530
01:30:32,950 --> 01:30:31,040
entire ribosome you can't touch it um so

2531
01:30:34,310 --> 01:30:32,960
you have to go for an in vivo approach

2532
01:30:35,910 --> 01:30:34,320
that's more high throughput when you

2533
01:30:37,750 --> 01:30:35,920
have it in cells

2534
01:30:40,390 --> 01:30:37,760
it's easier to assay

2535
01:30:42,470 --> 01:30:40,400
but because the ribosome is so central

2536
01:30:45,189 --> 01:30:42,480
once you start touching it in vivo the

2537
01:30:47,270 --> 01:30:45,199
cell dies because almost all mutations

2538
01:30:48,470 --> 01:30:47,280

are deleterious and it's so essential

2539
01:30:50,149 --> 01:30:48,480
for survival

2540
01:30:52,470 --> 01:30:50,159
so that's when we move on to an

2541
01:30:54,229 --> 01:30:52,480
orthogonal translation system

2542
01:30:56,310 --> 01:30:54,239
so here is an orthogonal translation

2543
01:30:59,430 --> 01:30:56,320
system in e coli

2544
01:31:01,669 --> 01:30:59,440
you maintain your native translation

2545
01:31:04,149 --> 01:31:01,679
system for all the

2546
01:31:05,990 --> 01:31:04,159
native processes so you still have your

2547
01:31:08,790 --> 01:31:06,000
proteins and then you have another

2548
01:31:10,950 --> 01:31:08,800
ribosome operating at the same time and

2549
01:31:13,270 --> 01:31:10,960
this is the orthogonal one and you have

2550
01:31:14,790 --> 01:31:13,280
your mrnas directed to which ribosome

2551
01:31:17,990 --> 01:31:14,800
they're going to go to so you have your

2552
01:31:19,350 --> 01:31:18,000
native mrna and your orthogonal mrna

2553
01:31:21,510 --> 01:31:19,360
but there are a few problems with this

2554
01:31:23,430 --> 01:31:21,520
system in e coli right now so as you can

2555
01:31:25,189 --> 01:31:23,440
see there's this like red tether between

2556
01:31:27,110 --> 01:31:25,199
these two the large subunit and the

2557
01:31:29,590 --> 01:31:27,120
small subunit and that's to prevent

2558
01:31:31,590 --> 01:31:29,600
franken ribosomes because how do these

2559
01:31:34,149 --> 01:31:31,600
large subunits know which small subunit

2560
01:31:36,149 --> 01:31:34,159
to go to so that's a big issue the other

2561
01:31:37,830 --> 01:31:36,159
issue is it's not just rna that makes up

2562
01:31:40,149 --> 01:31:37,840
ribosomes as i said before you've got

2563
01:31:42,390 --> 01:31:40,159

your ribosomal proteins and as the cells

2564
01:31:44,149 --> 01:31:42,400
divide and make more ribosomes they

2565
01:31:46,629 --> 01:31:44,159
don't know where the protein should go

2566
01:31:48,709 --> 01:31:46,639
to which ribosomes they should go to um

2567
01:31:50,470 --> 01:31:48,719
so they can't using this orthogonal

2568
01:31:53,750 --> 01:31:50,480
system you can't touch the ribosomal

2569
01:31:55,750 --> 01:31:53,760
proteins you can only touch the rrna

2570
01:31:58,229 --> 01:31:55,760
and even with that they can't touch the

2571
01:31:59,830 --> 01:31:58,239
peptidotransferase center so it's a very

2572
01:32:01,669 --> 01:31:59,840
limited system

2573
01:32:03,750 --> 01:32:01,679
which is why we thought the

2574
01:32:05,189 --> 01:32:03,760
saccharomyces cerevisiae mitochondrial

2575
01:32:08,149 --> 01:32:05,199
ribosome would make the perfect

2576
01:32:10,790 --> 01:32:08,159
orthogonal evolvable translation system

2577
01:32:14,149 --> 01:32:10,800
so saccharomyces cerevisiae are a type

2578
01:32:17,110 --> 01:32:14,159
of budding yeast and as eukaryotes they

2579
01:32:18,790 --> 01:32:17,120
have cytoplasmic ribosomes and ribosomes

2580
01:32:21,430 --> 01:32:18,800
in their mitochondria

2581
01:32:24,149 --> 01:32:21,440
and these mitochondrial ribosomes have

2582
01:32:26,550 --> 01:32:24,159
their rna mitochondrial encoded but

2583
01:32:28,550 --> 01:32:26,560
their proteins and the nucleus

2584
01:32:30,470 --> 01:32:28,560
and they're completely separate so their

2585
01:32:32,229 --> 01:32:30,480
translation doesn't affect each other

2586
01:32:34,550 --> 01:32:32,239
they um

2587
01:32:37,350 --> 01:32:34,560
while the ribosomal proteins are nuclear

2588
01:32:39,030 --> 01:32:37,360

encoded for the mitochondria they uh

2589
01:32:41,790 --> 01:32:39,040
have a specific sequence sending them to

2590
01:32:44,390 --> 01:32:41,800
mitochondria so there's no issue of like

2591
01:32:46,709 --> 01:32:44,400
cross-talking of these two

2592
01:32:49,830 --> 01:32:46,719
and so i have the system for using these

2593
01:32:53,189 --> 01:32:49,840
mitochondrial ribosomes as my system i

2594
01:32:55,270 --> 01:32:53,199
guess so we start with a perturbation of

2595
01:32:57,270 --> 01:32:55,280
the mitochondrial ribosome it could be

2596
01:32:59,750 --> 01:32:57,280
editing the mitochondrial ribosomal

2597
01:33:01,910 --> 01:32:59,760
proteins it could be some other kind of

2598
01:33:03,669 --> 01:33:01,920
stopping of myo-ribosome function and

2599
01:33:04,709 --> 01:33:03,679
when i do this there are two possible

2600
01:33:06,550 --> 01:33:04,719
outcomes

2601
01:33:09,110 --> 01:33:06,560
either i have functional mito ribosomes

2602
01:33:11,030 --> 01:33:09,120
or non-functional mito ribosomes so i

2603
01:33:12,870 --> 01:33:11,040
can test that using

2604
01:33:15,189 --> 01:33:12,880
a different type of carbon source in the

2605
01:33:16,709 --> 01:33:15,199
growth medium in this case it's glycerol

2606
01:33:19,350 --> 01:33:16,719
for these cells it's a non-fermentable

2607
01:33:21,110 --> 01:33:19,360
carbon source so they need mitochondrial

2608
01:33:22,870 --> 01:33:21,120
mitochondria functional to grow on this

2609
01:33:24,229 --> 01:33:22,880
non-fermentable carbon source we have

2610
01:33:26,629 --> 01:33:24,239
functional mutations non-functional

2611
01:33:28,229 --> 01:33:26,639
mutations but this isn't where the story

2612
01:33:30,629 --> 01:33:28,239
ends and this is what's special about

2613
01:33:33,030 --> 01:33:30,639

saccharomyces cerevisiae

2614
01:33:36,310 --> 01:33:33,040
they do not need functional mitochondria

2615
01:33:38,390 --> 01:33:36,320
to stay alive like we do so just because

2616
01:33:40,550 --> 01:33:38,400
the mutations are not functional doesn't

2617
01:33:42,310 --> 01:33:40,560
mean that the cells are dead so i can

2618
01:33:43,830 --> 01:33:42,320
take these cells with the non-functional

2619
01:33:45,750 --> 01:33:43,840
myo-ribosomes

2620
01:33:48,149 --> 01:33:45,760
and then continue to grow them in a

2621
01:33:50,470 --> 01:33:48,159
non-selective medium so using glucose as

2622
01:33:52,790 --> 01:33:50,480
the carbon source and this allows them

2623
01:33:54,229 --> 01:33:52,800
to accumulate spontaneous mutations as

2624
01:33:56,870 --> 01:33:54,239
cells divide

2625
01:33:59,110 --> 01:33:56,880
and then i can test to see if any of

2626
01:34:00,950 --> 01:33:59,120
these mutations are compensatory to

2627
01:34:01,910 --> 01:34:00,960
allow the mito ribosomes to function

2628
01:34:07,110 --> 01:34:01,920
again

2629
01:34:09,510 --> 01:34:07,120
to the glycerol as the carbon source

2630
01:34:13,510 --> 01:34:09,520
so to test my system i first started

2631
01:34:16,149 --> 01:34:13,520
with ml50 as a mitorible protein um here

2632
01:34:18,390 --> 01:34:16,159
we have the mito ribosome and then in

2633
01:34:20,229 --> 01:34:18,400
cyan we have this ml50

2634
01:34:21,669 --> 01:34:20,239
and i truncated it so i cut off that

2635
01:34:24,229 --> 01:34:21,679
part in red

2636
01:34:26,310 --> 01:34:24,239
and this is a mitochondrial specific uh

2637
01:34:27,990 --> 01:34:26,320
protein so we don't see it in

2638
01:34:29,350 --> 01:34:28,000

our cytoplasmic ribosomes or anything

2639
01:34:31,110 --> 01:34:29,360
like that and i found with this

2640
01:34:33,590 --> 01:34:31,120
truncation that all these cells are

2641
01:34:35,430 --> 01:34:33,600
actually ypg positive so they can grow

2642
01:34:36,709 --> 01:34:35,440
in the non-preventable carbon source

2643
01:34:39,110 --> 01:34:36,719
which means their mito ribosomes are

2644
01:34:41,270 --> 01:34:39,120
functional but that gives us a very

2645
01:34:43,510 --> 01:34:41,280
limited view so i have this strain of

2646
01:34:45,270 --> 01:34:43,520
yeast with gfp that's encoded on the

2647
01:34:48,470 --> 01:34:45,280
mitochondrial genome so i can use this

2648
01:34:51,350 --> 01:34:48,480
as a readout of my ribosome function

2649
01:34:54,950 --> 01:34:51,360
and that's what i did here so in red we

2650
01:34:57,910 --> 01:34:54,960
have a type of wild type yeast so it's a

2651
01:34:59,109 --> 01:34:57,920
non-fluorescent strain in blue we have

2652
01:35:01,030 --> 01:34:59,119
the positive control so it's a

2653
01:35:03,430 --> 01:35:01,040
fluorescent strain and then in orange we

2654
01:35:04,629 --> 01:35:03,440
have the truncated protein and i grew

2655
01:35:06,629 --> 01:35:04,639
these and ran them through the flow

2656
01:35:09,030 --> 01:35:06,639
cytometer which measures size and

2657
01:35:12,070 --> 01:35:09,040
fluorescence per cell this is all on the

2658
01:35:14,310 --> 01:35:12,080
single cell level and here we have some

2659
01:35:16,070 --> 01:35:14,320
flow cytometer result so this is average

2660
01:35:17,750 --> 01:35:16,080
fluorescence per cell in relative

2661
01:35:20,870 --> 01:35:17,760
fluorescent units and then these are the

2662
01:35:23,590 --> 01:35:20,880
two media types so using ypd which is

2663
01:35:25,750 --> 01:35:23,600

glucose and then ypg which is the

2664
01:35:26,790 --> 01:35:25,760
glycerol and once again the glycerol

2665
01:35:28,790 --> 01:35:26,800
means we have to have functional

2666
01:35:30,310 --> 01:35:28,800
mitochondria and with the

2667
01:35:33,750 --> 01:35:30,320
non-fluorescent strain we have low

2668
01:35:35,109 --> 01:35:33,760
levels of fluorescence and then with the

2669
01:35:36,870 --> 01:35:35,119
no truncation we have a high level

2670
01:35:38,550 --> 01:35:36,880
fluorescence and then an actual a

2671
01:35:41,030 --> 01:35:38,560
significant decrease in fluorescence

2672
01:35:43,189 --> 01:35:41,040
with the truncation so this shows that

2673
01:35:44,870 --> 01:35:43,199
even this mida ribosomal truncation

2674
01:35:46,790 --> 01:35:44,880
while we still have function

2675
01:35:48,950 --> 01:35:46,800
we have a decrease in function and then

2676
01:35:52,550 --> 01:35:48,960
on the right here we have this histogram

2677
01:35:55,030 --> 01:35:52,560
showing um in the same colors the peak

2678
01:35:56,950 --> 01:35:55,040
shifts with the different types of

2679
01:35:58,550 --> 01:35:56,960
ribosomes

2680
01:36:00,709 --> 01:35:58,560
and then as i said earlier we were

2681
01:36:02,550 --> 01:36:00,719
talking about perturbations so i can

2682
01:36:04,709 --> 01:36:02,560
easily touch these

2683
01:36:07,590 --> 01:36:04,719
proteins but i can't touch the rrna

2684
01:36:09,750 --> 01:36:07,600
because it is mitochondrial encoded but

2685
01:36:13,350 --> 01:36:09,760
there's another way i can perturb the

2686
01:36:16,149 --> 01:36:13,360
rrna so mito ribosomes are actually more

2687
01:36:18,470 --> 01:36:16,159
similar to bacterial ribosomes than like

2688
01:36:20,790 --> 01:36:18,480

their cytoplasmic counterparts so you

2689
01:36:23,510 --> 01:36:20,800
can use antibiotics to selectively

2690
01:36:24,870 --> 01:36:23,520
target mito ribosomes that you can't

2691
01:36:26,149 --> 01:36:24,880
without touching the cytoplasmic

2692
01:36:28,550 --> 01:36:26,159
ribosomes

2693
01:36:30,310 --> 01:36:28,560
and i started with chloramphenicol so

2694
01:36:31,430 --> 01:36:30,320
chloramphenicol prevents peptidal

2695
01:36:33,350 --> 01:36:31,440
transfer

2696
01:36:35,430 --> 01:36:33,360
um usually in bacteria so this is an e

2697
01:36:38,390 --> 01:36:35,440
coli ribosome right here um in the

2698
01:36:41,189 --> 01:36:38,400
peptidyl transferase center

2699
01:36:43,430 --> 01:36:41,199
and then it is known that mitori mitor

2700
01:36:46,149 --> 01:36:43,440
ribosomes particularly saccharomyces or

2701
01:36:49,350 --> 01:36:46,159
vcimitor ribosomes can accumulate one

2702
01:36:52,790 --> 01:36:49,360
single nucleotide polymorphism to have

2703
01:36:54,709 --> 01:36:52,800
um chloramphenicol resistance

2704
01:36:56,550 --> 01:36:54,719
so i went through this evolution

2705
01:36:57,590 --> 01:36:56,560
experiment using my workflow i showed

2706
01:37:00,470 --> 01:36:57,600
before

2707
01:37:03,270 --> 01:37:00,480
and uh here we have some suppressor

2708
01:37:05,270 --> 01:37:03,280
mutants i was able to get so we have

2709
01:37:07,189 --> 01:37:05,280
wild type up here and that was the

2710
01:37:09,910 --> 01:37:07,199
original strain and then down here we

2711
01:37:12,070 --> 01:37:09,920
have five suppressor strains and then i

2712
01:37:14,310 --> 01:37:12,080
sequenced their 21s found the single

2713
01:37:16,629 --> 01:37:14,320

nucleotide polymorphism and then used

2714
01:37:19,990 --> 01:37:16,639
that strain in the flow cytometer to see

2715
01:37:22,550 --> 01:37:20,000
what happens to mito ribosome function

2716
01:37:23,990 --> 01:37:22,560
so um we once again have this bar chart

2717
01:37:26,790 --> 01:37:24,000
on the left with the fluorescence per

2718
01:37:30,229 --> 01:37:26,800
cell and we now have added instead of

2719
01:37:31,189 --> 01:37:30,239
just the ypd and ypg chloramphenicol to

2720
01:37:32,390 --> 01:37:31,199
the mix

2721
01:37:34,310 --> 01:37:32,400
so

2722
01:37:36,390 --> 01:37:34,320
with just ypg we have very similar

2723
01:37:39,030 --> 01:37:36,400
levels of fluorescence between the

2724
01:37:40,870 --> 01:37:39,040
positive strain and the chloramphenicol

2725
01:37:43,109 --> 01:37:40,880
resistance strain and then once we move

2726
01:37:45,189 --> 01:37:43,119
to ypg plus chloramphenicol only the

2727
01:37:47,510 --> 01:37:45,199
chloramphenicol resistance strain

2728
01:37:49,910 --> 01:37:47,520
um is fluorescent and has a very similar

2729
01:37:51,350 --> 01:37:49,920
level of fluorescence so what we can say

2730
01:37:53,510 --> 01:37:51,360
here is that the chloramphenicol

2731
01:37:55,510 --> 01:37:53,520
resistance um does not inhibit

2732
01:37:57,830 --> 01:37:55,520
mitoribsome function even though there

2733
01:38:01,270 --> 01:37:57,840
is a mutation in the 21s of the

2734
01:38:03,189 --> 01:38:01,280
mitoribosom and here is the histogram

2735
01:38:05,990 --> 01:38:03,199
with gfp fluorescence on the bottom

2736
01:38:09,669 --> 01:38:06,000
showing the peak shifts when we have

2737
01:38:12,310 --> 01:38:09,679
chloramphenicol in the ypg

2738
01:38:14,790 --> 01:38:12,320

and with that i would like to share my

2739
01:38:16,310 --> 01:38:14,800
conclusions that the s-cerevisiae and

2740
01:38:18,070 --> 01:38:16,320
myo-ribosome

2741
01:38:19,590 --> 01:38:18,080
function decreases the short truncation

2742
01:38:21,910 --> 01:38:19,600
of ml50

2743
01:38:23,669 --> 01:38:21,920
a compensatory mutation in the 21s of

2744
01:38:25,189 --> 01:38:23,679
the mida ribosome gives resistance to

2745
01:38:27,189 --> 01:38:25,199
chloramphenicol without hindering

2746
01:38:29,990 --> 01:38:27,199
function and lastly maybe most

2747
01:38:31,990 --> 01:38:30,000
importantly the esser of seimitoribosome

2748
01:38:34,550 --> 01:38:32,000
is an isolated orthogonal evolvable

2749
01:38:36,550 --> 01:38:34,560
translation system that we can then use

2750
01:38:38,870 --> 01:38:36,560
to do further perturbations of the

2751
01:38:40,629 --> 01:38:38,880
ribosome

2752
01:38:42,310 --> 01:38:40,639
and i would like to thank lauren

2753
01:38:44,790 --> 01:38:42,320
williams mypi

2754
01:38:46,310 --> 01:38:44,800
and karil lobachev and wen ying because

2755
01:38:48,310 --> 01:38:46,320
they've been so instrumental in getting

2756
01:38:50,470 --> 01:38:48,320
me started in yeast and then lastly

2757
01:38:52,390 --> 01:38:50,480
professor martin ought from the

2758
01:38:55,820 --> 01:38:52,400
university of stockholm for kindly

2759
01:39:00,310 --> 01:38:55,830
gifting me this strain of yeast

2760
01:39:07,669 --> 01:39:00,320
[Applause]

2761
01:39:10,870 --> 01:39:09,270
hey so so i think this is probably a

2762
01:39:12,470 --> 01:39:10,880
pretty simple question because i don't

2763
01:39:15,430 --> 01:39:12,480

have much background in this stuff but

2764
01:39:17,430 --> 01:39:15,440
how does the cell keep living once you

2765
01:39:19,990 --> 01:39:17,440
once the mito ribosome doesn't function

2766
01:39:22,709 --> 01:39:20,000
anymore what what replaces its function

2767
01:39:23,990 --> 01:39:22,719
so as long as you're growing it um on

2768
01:39:25,990 --> 01:39:24,000
glucose

2769
01:39:28,229 --> 01:39:26,000
you don't need functional mitochondria

2770
01:39:30,550 --> 01:39:28,239
okay so they just don't use them at all

2771
01:39:34,149 --> 01:39:30,560
so so does the glucose somehow replace

2772
01:39:38,070 --> 01:39:36,790
that was my question thank you

2773
01:39:41,270 --> 01:39:38,080
thanks

2774
01:39:45,350 --> 01:39:43,910
so did you say you were going to be uh

2775
01:39:47,990 --> 01:39:45,360
evolving

2776
01:39:49,669 --> 01:39:48,000
them in response to protein mutation as

2777
01:39:51,590 --> 01:39:49,679
well like the uh

2778
01:39:52,310 --> 01:39:51,600
yeah so that's that's in progress right

2779
01:39:56,550 --> 01:39:52,320
okay

2780
01:39:59,990 --> 01:39:56,560
yeah so um do do you have any

2781
01:40:03,189 --> 01:40:00,000
um intuition as to the number as to how

2782
01:40:04,870 --> 01:40:03,199
many generations that might take

2783
01:40:06,870 --> 01:40:04,880
um

2784
01:40:08,629 --> 01:40:06,880
in lauren williams level we do the the

2785
01:40:11,270 --> 01:40:08,639
evolution experiments and i'd love to

2786
01:40:13,030 --> 01:40:11,280
talk to you about that sometime yeah so

2787
01:40:15,510 --> 01:40:13,040
um we've done some successfully with

2788
01:40:17,109 --> 01:40:15,520

truncations where i don't measure like

2789
01:40:20,149 --> 01:40:17,119
number of generations but we're talking

2790
01:40:22,310 --> 01:40:20,159
about like growing in liquid overnight

2791
01:40:24,629 --> 01:40:22,320
plating on ypd for a few days and then

2792
01:40:26,790 --> 01:40:24,639
replica plating to ypg so we're not

2793
01:40:28,629 --> 01:40:26,800
talking about long periods of time so

2794
01:40:30,149 --> 01:40:28,639
they're so they're they're

2795
01:40:31,750 --> 01:40:30,159
fixing themselves

2796
01:40:33,430 --> 01:40:31,760
in a reasonably short period of time

2797
01:40:34,870 --> 01:40:33,440
from these purposes yes and the

2798
01:40:37,109 --> 01:40:34,880
chloramphenicol resistant ones were

2799
01:40:38,709 --> 01:40:37,119
actually really fast okay so this is so

2800
01:40:40,629 --> 01:40:38,719
these are height so you're actually

2801
01:40:42,229 --> 01:40:40,639
finding highly accessible

2802
01:40:43,750 --> 01:40:42,239
uh evolution

2803
01:40:45,830 --> 01:40:43,760
yeah i'm sure the like larger

2804
01:40:47,910 --> 01:40:45,840
perturbations we do um we might have to

2805
01:40:49,590 --> 01:40:47,920
add like a chemical mutagen but

2806
01:40:51,430 --> 01:40:49,600
yeah but still so so it's so it's

2807
01:40:55,350 --> 01:40:51,440
working fast and well that's that's

2808
01:41:00,310 --> 01:40:57,750
and do you have any other questions

2809
01:41:03,040 --> 01:41:00,320
or anything from online

2810
01:41:08,390 --> 01:41:03,050
all right we can move on then thank you

2811
01:41:13,030 --> 01:41:10,950
and our last talk of the day is anthony

2812
01:41:15,350 --> 01:41:13,040
vernetti presenting on the dual origins

2813
01:41:17,109 --> 01:41:15,360

of phototrophy reveals the importance of

2814
01:41:19,430 --> 01:41:17,119
evolutionary priority effects and major

2815
01:41:21,430 --> 01:41:19,440
transitions

2816
01:41:23,109 --> 01:41:21,440
all right

2817
01:41:24,070 --> 01:41:23,119
and is this

2818
01:41:32,629 --> 01:41:24,080
gonna work

2819
01:41:36,229 --> 01:41:34,390
all right

2820
01:41:38,950 --> 01:41:36,239
so yes uh

2821
01:41:41,669 --> 01:41:38,960
my name is anthony i work with uh

2822
01:41:43,669 --> 01:41:41,679
will ratcliffe here at georgia tech

2823
01:41:47,270 --> 01:41:43,679
um ordinarily

2824
01:41:49,590 --> 01:41:47,280
i work with yeast most of the time but

2825
01:41:51,590 --> 01:41:49,600
and we actually um study the evolution

2826
01:41:53,189 --> 01:41:51,600
of multicellularity using yeast but that

2827
01:41:55,830 --> 01:41:53,199
got me interested

2828
01:41:58,470 --> 01:41:55,840
in studying other major evolutionary

2829
01:42:01,270 --> 01:41:58,480
transitions not necessarily in the lab

2830
01:42:03,430 --> 01:42:01,280
but by looking at uh the hit by looking

2831
01:42:04,950 --> 01:42:03,440
at the history of life uh

2832
01:42:06,870 --> 01:42:04,960
as it exists on earth i think there's

2833
01:42:08,229 --> 01:42:06,880
some very interesting things

2834
01:42:10,390 --> 01:42:08,239
that you can tell

2835
01:42:11,990 --> 01:42:10,400
so uh

2836
01:42:14,950 --> 01:42:12,000
the big question

2837
01:42:17,109 --> 01:42:14,960
that uh got interesting to me was are

2838
01:42:19,350 --> 01:42:17,119

major evolutionary innovations and

2839
01:42:21,189 --> 01:42:19,360
transitions predictable or are they

2840
01:42:23,430 --> 01:42:21,199
contingent um

2841
01:42:25,669 --> 01:42:23,440
and people have been trying to answer

2842
01:42:28,390 --> 01:42:25,679
this question forever and everyone's

2843
01:42:31,430 --> 01:42:28,400
looking at the same thing and coming to

2844
01:42:33,830 --> 01:42:31,440
wildly different conclusions um you've

2845
01:42:37,030 --> 01:42:33,840
you've got there's this wonderful uh

2846
01:42:39,109 --> 01:42:37,040
book from manon in 70s where he looks at

2847
01:42:41,830 --> 01:42:39,119
bacterial biochemistry and says oh my

2848
01:42:44,870 --> 01:42:41,840
god this is so bizarre we finally know

2849
01:42:46,950 --> 01:42:44,880
we're alone in the universe and and and

2850
01:42:49,189 --> 01:42:46,960
other people look at the whole history

2851
01:42:51,350 --> 01:42:49,199
of life on earth and say okay this makes

2852
01:42:52,470 --> 01:42:51,360
sense why why why would this not be

2853
01:42:54,790 --> 01:42:52,480
something that would just

2854
01:42:56,550 --> 01:42:54,800
straightforwardly happen and so what

2855
01:42:58,950 --> 01:42:56,560
this tells me is that people are not

2856
01:43:00,950 --> 01:42:58,960
looking at this systematically they they

2857
01:43:03,109 --> 01:43:00,960
um they are using

2858
01:43:05,109 --> 01:43:03,119
wildly varying intuitions and so i think

2859
01:43:06,950 --> 01:43:05,119
um it would be useful to try to look at

2860
01:43:09,030 --> 01:43:06,960
this systematically and figure out

2861
01:43:11,270 --> 01:43:09,040
what's actually going on

2862
01:43:13,990 --> 01:43:11,280
so there are some

2863
01:43:16,950 --> 01:43:14,000

major evolutionary innovations that

2864
01:43:18,470 --> 01:43:16,960
appear again and again and again

2865
01:43:21,590 --> 01:43:18,480
um and

2866
01:43:23,990 --> 01:43:21,600
this is a beautiful tree of uh the

2867
01:43:26,629 --> 01:43:24,000
eukaryotes every clade in there that has

2868
01:43:28,870 --> 01:43:26,639
any yellow on it has multi-cellular

2869
01:43:30,390 --> 01:43:28,880
uh instances and that's not it that

2870
01:43:32,149 --> 01:43:30,400
that's not derived from the beginning

2871
01:43:34,070 --> 01:43:32,159
that's every every one of those has

2872
01:43:35,910 --> 01:43:34,080
separately invented it it just happens

2873
01:43:38,310 --> 01:43:35,920
over and over

2874
01:43:40,790 --> 01:43:38,320
and so this is fairly predictable this

2875
01:43:42,709 --> 01:43:40,800
is something that uh is easy it happens

2876
01:43:44,709 --> 01:43:42,719
all the time

2877
01:43:45,910 --> 01:43:44,719
but there's a lot of innovations that

2878
01:43:47,189 --> 01:43:45,920
people call

2879
01:43:48,390 --> 01:43:47,199
well not a lot there are multiple

2880
01:43:50,790 --> 01:43:48,400
innovations that people call

2881
01:43:53,350 --> 01:43:50,800
evolutionary singularities these are

2882
01:43:54,709 --> 01:43:53,360
things that happened once and only once

2883
01:43:57,590 --> 01:43:54,719
and changed the world and people are

2884
01:43:59,669 --> 01:43:57,600
very interested in these um the

2885
01:44:01,669 --> 01:43:59,679
classic one is of course

2886
01:44:04,550 --> 01:44:01,679
origin of the translation in genetic

2887
01:44:07,750 --> 01:44:04,560
code that's a heck of a big deal um

2888
01:44:08,629 --> 01:44:07,760

origin of eukaryotes is very important

2889
01:44:10,870 --> 01:44:08,639
um

2890
01:44:12,550 --> 01:44:10,880
and so why are these things singular

2891
01:44:15,109 --> 01:44:12,560
these could be extremely unlikely to

2892
01:44:17,430 --> 01:44:15,119
evolve and we only see them because of

2893
01:44:19,910 --> 01:44:17,440
an anthropic selection effect like we're

2894
01:44:21,830 --> 01:44:19,920
here because interesting things happened

2895
01:44:22,629 --> 01:44:21,840
meaning that we can look at it

2896
01:44:26,629 --> 01:44:22,639
or

2897
01:44:28,310 --> 01:44:26,639
process that limits what you can

2898
01:44:29,750 --> 01:44:28,320
actually see

2899
01:44:32,550 --> 01:44:29,760
and uh

2900
01:44:34,390 --> 01:44:32,560
and what is there today so how can we

2901
01:44:39,109 --> 01:44:34,400
look at this

2902
01:44:42,470 --> 01:44:39,119
at a phototrophy phototrophy is the

2903
01:44:43,669 --> 01:44:42,480
ability to use light for biological

2904
01:44:45,990 --> 01:44:43,679
energy

2905
01:44:48,870 --> 01:44:46,000
and i would argue that this is the

2906
01:44:51,350 --> 01:44:48,880
second most important major evolutionary

2907
01:44:54,709 --> 01:44:51,360
innovation after

2908
01:44:56,870 --> 01:44:54,719
translation itself basically because um

2909
01:45:00,550 --> 01:44:56,880
non-phototrophic primary production is

2910
01:45:02,870 --> 01:45:00,560
barely any of the total biomass of earth

2911
01:45:06,790 --> 01:45:02,880
the the vast majority

2912
01:45:09,910 --> 01:45:06,800
of biomass comes from using light to fix

2913
01:45:12,310 --> 01:45:09,920

carbon and um it's not a coincidence

2914
01:45:14,550 --> 01:45:12,320
that the earliest evidence of life on

2915
01:45:16,790 --> 01:45:14,560
earth that nobody disagrees with is

2916
01:45:18,709 --> 01:45:16,800
photosynthetic microbial mass this this

2917
01:45:20,950 --> 01:45:18,719
this is not an accident this is it

2918
01:45:22,390 --> 01:45:20,960
changed everything um

2919
01:45:23,750 --> 01:45:22,400
it take it takes the earth from

2920
01:45:26,229 --> 01:45:23,760
something where you might not notice it

2921
01:45:27,910 --> 01:45:26,239
was alive if you were standing on it to

2922
01:45:30,390 --> 01:45:27,920
something where you can see the

2923
01:45:33,189 --> 01:45:30,400
atmosphere is weird across the galaxy

2924
01:45:35,270 --> 01:45:33,199
with a good instrument so um

2925
01:45:36,070 --> 01:45:35,280
i would say this is fairly important

2926
01:45:38,070 --> 01:45:36,080
um

2927
01:45:40,310 --> 01:45:38,080
the interesting thing though phototrophy

2928
01:45:42,629 --> 01:45:40,320
was invented twice

2929
01:45:44,229 --> 01:45:42,639
not once it's not singular but it's not

2930
01:45:46,950 --> 01:45:44,239
like multicellularity with it being

2931
01:45:47,750 --> 01:45:46,960
invented a bunch of times and two

2932
01:45:50,310 --> 01:45:47,760
is

2933
01:45:52,629 --> 01:45:50,320
interesting it it provides information

2934
01:45:55,510 --> 01:45:52,639
because you can compare the two against

2935
01:45:57,990 --> 01:45:55,520
each other but it's still rare it means

2936
01:46:00,310 --> 01:45:58,000
that there is something limiting the

2937
01:46:02,629 --> 01:46:00,320
number of instances that you see and so

2938
01:46:05,590 --> 01:46:02,639

i think this is an important window into

2939
01:46:08,229 --> 01:46:05,600
things that are truly singular

2940
01:46:10,629 --> 01:46:08,239
and this has happened like i said twice

2941
01:46:12,870 --> 01:46:10,639
it's happened in retinal phototrophs and

2942
01:46:14,629 --> 01:46:12,880
chlorophototrophs chlorophototrophs

2943
01:46:17,350 --> 01:46:14,639
everything green you see outside is a

2944
01:46:19,510 --> 01:46:17,360
subset of that um and written aloe

2945
01:46:21,350 --> 01:46:19,520
phototrophs uh they're generally purple

2946
01:46:22,950 --> 01:46:21,360
they're all microbes uh you see them

2947
01:46:25,030 --> 01:46:22,960
flying over salt flats is where you're

2948
01:46:26,950 --> 01:46:25,040
most likely to actually see them in your

2949
01:46:27,910 --> 01:46:26,960
in your day-to-day life

2950
01:46:28,790 --> 01:46:27,920
so

2951
01:46:31,350 --> 01:46:28,800
um

2952
01:46:35,510 --> 01:46:31,360
like i said very important window into

2953
01:46:37,350 --> 01:46:35,520
evolutionary innovation i want to uh

2954
01:46:38,470 --> 01:46:37,360
see why we're looking at two why we're

2955
01:46:40,950 --> 01:46:38,480
seeing two

2956
01:46:43,590 --> 01:46:40,960
and also how they compare to each other

2957
01:46:46,390 --> 01:46:43,600
so this is the wrong um this is the

2958
01:46:49,590 --> 01:46:46,400
wrong uh file so

2959
01:46:51,350 --> 01:46:49,600
let's see this is a i i am pretty sure

2960
01:46:53,109 --> 01:46:51,360
that's this this is this is indeed the

2961
01:46:57,300 --> 01:46:53,119
wrong file can i put something on from

2962
01:46:57,310 --> 01:47:05,510
[Music]

2963
01:47:11,669 --> 01:47:08,709

okay i got it i got it from here

2964
01:47:14,629 --> 01:47:13,910
let's see

2965
01:47:16,709 --> 01:47:14,639
or

2966
01:47:24,550 --> 01:47:16,719
the other one

2967
01:47:24,560 --> 01:47:27,910
there we are

2968
01:47:27,920 --> 01:47:32,070
got it

2969
01:47:32,080 --> 01:47:35,350
there we go

2970
01:47:38,870 --> 01:47:36,390
sorry about the

2971
01:47:41,830 --> 01:47:38,880
slight issue there so um let's take a

2972
01:47:44,790 --> 01:47:41,840
look at the two different uh instances

2973
01:47:46,629 --> 01:47:44,800
of phototrophy on earth so uh

2974
01:47:48,790 --> 01:47:46,639
the first one i'm gonna look at is

2975
01:47:51,270 --> 01:47:48,800
microbial rhodopsins this is what

2976
01:47:54,470 --> 01:47:51,280
mediates phototrophy this system is just

2977
01:47:56,390 --> 01:47:54,480
a single 27 kilo dalton membrane protein

2978
01:47:59,430 --> 01:47:56,400
got a little dye molecule in it it

2979
01:48:01,109 --> 01:47:59,440
absorbs one photon and pumps one proton

2980
01:48:03,750 --> 01:48:01,119
every time that it runs

2981
01:48:05,590 --> 01:48:03,760
um and it's it gathers a small fraction

2982
01:48:08,709 --> 01:48:05,600
of the energy of that photon

2983
01:48:10,870 --> 01:48:08,719
and it's really simple um this is the

2984
01:48:13,669 --> 01:48:10,880
entire functional unit you need

2985
01:48:15,910 --> 01:48:13,679
two to five genes to make the pigment so

2986
01:48:17,910 --> 01:48:15,920
this horizontally transfers like mad

2987
01:48:21,510 --> 01:48:17,920
it's all over the place it's in bacteria

2988
01:48:22,950 --> 01:48:21,520

archaea eukaryotes everywhere and um

2989
01:48:26,550 --> 01:48:22,960
this is a nice way to just get a little

2990
01:48:28,390 --> 01:48:26,560
bit of energy from uh from from light

2991
01:48:30,470 --> 01:48:28,400
then you've got the chlorophototrophic

2992
01:48:33,030 --> 01:48:30,480
reaction centers these

2993
01:48:34,550 --> 01:48:33,040
are extraordinarily different these are

2994
01:48:35,990 --> 01:48:34,560
these are horribly

2995
01:48:38,149 --> 01:48:36,000
complicated this is oxygenic

2996
01:48:41,030 --> 01:48:38,159
photosynthesis and many other groups of

2997
01:48:42,550 --> 01:48:41,040
bacteria um you've got dozens of

2998
01:48:43,510 --> 01:48:42,560
chlorophyll and bacterial chlorophyll

2999
01:48:45,910 --> 01:48:43,520
pigments

3000
01:48:48,390 --> 01:48:45,920
other things redox cofactors everything

3001
01:48:50,149 --> 01:48:48,400
in an enormous multi-protein uh complex

3002
01:48:52,149 --> 01:48:50,159
and this is which is itself part of an

3003
01:48:52,950 --> 01:48:52,159
electron transport chain

3004
01:48:54,950 --> 01:48:52,960
so

3005
01:48:57,270 --> 01:48:54,960
and this moves around electrons via

3006
01:48:59,030 --> 01:48:57,280
photochemistry um and so by plugging

3007
01:49:01,750 --> 01:48:59,040
this into an electron transport chain

3008
01:49:04,229 --> 01:49:01,760
every photon you absorb you can pump two

3009
01:49:05,669 --> 01:49:04,239
to four protons across the membrane and

3010
01:49:07,109 --> 01:49:05,679
charge it up and this and it depends on

3011
01:49:08,390 --> 01:49:07,119
the exact electron transport chain

3012
01:49:09,510 --> 01:49:08,400
you're plugged into it's it's super

3013
01:49:11,990 --> 01:49:09,520

flexible

3014
01:49:13,669 --> 01:49:12,000
and you can also use it to fix carbon

3015
01:49:15,750 --> 01:49:13,679
because you can shoot electrons up to

3016
01:49:17,510 --> 01:49:15,760
energy levels that can be used to to

3017
01:49:19,189 --> 01:49:17,520
reduce the co2 and in order to

3018
01:49:21,830 --> 01:49:19,199
horizontally transfer this

3019
01:49:23,910 --> 01:49:21,840
you need to transfer 30 genes it does

3020
01:49:25,990 --> 01:49:23,920
happen over evolutionary time but it's

3021
01:49:29,270 --> 01:49:26,000
but it's rare that you can you can look

3022
01:49:30,950 --> 01:49:29,280
at a tree and of of life and count the

3023
01:49:31,990 --> 01:49:30,960
number of times it uh it probably

3024
01:49:32,709 --> 01:49:32,000
happened

3025
01:49:34,550 --> 01:49:32,719
so

3026
01:49:36,470 --> 01:49:34,560
these things are very different and yes

3027
01:49:39,030 --> 01:49:36,480
this is this is the kind that this is

3028
01:49:41,350 --> 01:49:39,040
the most complicated uh system this is

3029
01:49:43,910 --> 01:49:41,360
the one that actually makes oxygen it

3030
01:49:45,990 --> 01:49:43,920
gets as simple as that so now this is

3031
01:49:47,910 --> 01:49:46,000
this is this is

3032
01:49:49,189 --> 01:49:47,920
this this is much more complicated than

3033
01:49:50,070 --> 01:49:49,199
the other version

3034
01:49:52,950 --> 01:49:50,080
so

3035
01:49:54,390 --> 01:49:52,960
little bit they're just very different

3036
01:49:56,950 --> 01:49:54,400
systems you've got this simple system

3037
01:49:58,950 --> 01:49:56,960
that just pumps one proton per photon

3038
01:50:02,070 --> 01:49:58,960

you got this enormous system that also

3039
01:50:04,229 --> 01:50:02,080
plugs into uh antenna pigments that sort

3040
01:50:06,950 --> 01:50:04,239
of funnel light into it and plugs into

3041
01:50:08,790 --> 01:50:06,960
an electron transport chain um and these

3042
01:50:11,270 --> 01:50:08,800
things are different in so many ways and

3043
01:50:13,030 --> 01:50:11,280
the light they absorb the elements that

3044
01:50:14,950 --> 01:50:13,040
are in them i'm not going to talk about

3045
01:50:17,910 --> 01:50:14,960
that right now i'm just going to talk

3046
01:50:19,750 --> 01:50:17,920
about one particular difference between

3047
01:50:22,149 --> 01:50:19,760
them and that is

3048
01:50:24,950 --> 01:50:22,159
the has to do with their energy flux and

3049
01:50:26,550 --> 01:50:24,960
yield versus their mass and you get this

3050
01:50:27,669 --> 01:50:26,560
just by looking at the size of the

3051
01:50:30,709 --> 01:50:27,679
system

3052
01:50:31,830 --> 01:50:30,719
how fast it turns over and what it

3053
01:50:34,629 --> 01:50:31,840
produces

3054
01:50:36,310 --> 01:50:34,639
and uh bri and bringing these numbers uh

3055
01:50:38,790 --> 01:50:36,320
together and turns out this tells you

3056
01:50:41,189 --> 01:50:38,800
something super interesting

3057
01:50:44,790 --> 01:50:41,199
um this is a graph

3058
01:50:46,550 --> 01:50:44,800
of the energy flux per unit mass when

3059
01:50:48,070 --> 01:50:46,560
the system is running full tilt i dug up

3060
01:50:49,669 --> 01:50:48,080
a bunch of information on a bunch of

3061
01:50:51,669 --> 01:50:49,679
different systems i got two

3062
01:50:53,669 --> 01:50:51,679
chlorophotrophic systems and two retinal

3063
01:50:55,990 --> 01:50:53,679

phototrophic systems the retinal's

3064
01:50:57,669 --> 01:50:56,000
churning energy like crazy per unit mass

3065
01:50:59,750 --> 01:50:57,679
when it's at saturation

3066
01:51:01,430 --> 01:50:59,760
and so and that's because yeah they

3067
01:51:03,350 --> 01:51:01,440
they're not as good they're inefficient

3068
01:51:05,510 --> 01:51:03,360
they run slower but they're tiny you get

3069
01:51:06,950 --> 01:51:05,520
you get you get um an enormous flux per

3070
01:51:08,070 --> 01:51:06,960
unit mass

3071
01:51:10,070 --> 01:51:08,080
um

3072
01:51:12,870 --> 01:51:10,080
it's and it's really low fluxes per unit

3073
01:51:13,910 --> 01:51:12,880
mass for the for the chlorophyll and so

3074
01:51:16,870 --> 01:51:13,920
um

3075
01:51:19,109 --> 01:51:16,880
you get an enormous return on investment

3076
01:51:21,109 --> 01:51:19,119
for for the same mass of rhodopsin

3077
01:51:22,390 --> 01:51:21,119
versus a versus a chlorophototrophic

3078
01:51:24,470 --> 01:51:22,400
system

3079
01:51:26,550 --> 01:51:24,480
but at the same time this larger

3080
01:51:28,149 --> 01:51:26,560
machinery it also absorbs a lot more

3081
01:51:30,709 --> 01:51:28,159
light it's full of lots and lots of

3082
01:51:31,669 --> 01:51:30,719
pigment and so uh if you actually look

3083
01:51:33,669 --> 01:51:31,679
at them

3084
01:51:36,629 --> 01:51:33,679
at different light levels

3085
01:51:39,109 --> 01:51:36,639
at low light the chlorophyll winds hands

3086
01:51:41,270 --> 01:51:39,119
down these two lines if at really low

3087
01:51:44,390 --> 01:51:41,280
levels this one this orange line here

3088
01:51:45,910 --> 01:51:44,400

actually wins handily at low light

3089
01:51:47,669 --> 01:51:45,920
levels the chlorophyll wins handily at

3090
01:51:50,070 --> 01:51:47,679
highlight levels the

3091
01:51:51,910 --> 01:51:50,080
retinal winds handily

3092
01:51:54,070 --> 01:51:51,920
so the chlorophytotrophs are efficient

3093
01:51:55,189 --> 01:51:54,080
per incident photon but then they

3094
01:51:58,229 --> 01:51:55,199
saturate

3095
01:52:00,790 --> 01:51:58,239
the retinal is efficient per unit

3096
01:52:03,510 --> 01:52:00,800
infrastructure when the resource is

3097
01:52:06,149 --> 01:52:03,520
abundant so now this is looking at a

3098
01:52:08,790 --> 01:52:06,159
couple of systems that exist in life

3099
01:52:11,830 --> 01:52:08,800
today i can do better than this

3100
01:52:15,750 --> 01:52:11,840
i um i have um actually managed to

3101
01:52:18,790 --> 01:52:15,760
create this simplified numerical model

3102
01:52:20,470 --> 01:52:18,800
of just a generic phototrophic system

3103
01:52:23,030 --> 01:52:20,480
this can be applied to either

3104
01:52:26,149 --> 01:52:23,040
chlorophototrophs or retinal phototrophs

3105
01:52:27,830 --> 01:52:26,159
you take a central engine as a given in

3106
01:52:29,589 --> 01:52:27,840
orange here

3107
01:52:32,070 --> 01:52:29,599
it's got a certain amount of absorption

3108
01:52:33,750 --> 01:52:32,080
it can do it has a velocity a yield

3109
01:52:35,350 --> 01:52:33,760
and then you have different amounts of

3110
01:52:37,430 --> 01:52:35,360
antennas

3111
01:52:39,430 --> 01:52:37,440
and this is this is a feature of

3112
01:52:43,189 --> 01:52:39,440
everything that uses chlorophyll and

3113
01:52:44,629 --> 01:52:43,199

some things that use retinal and um

3114
01:52:46,790 --> 01:52:44,639
and then you have and then this whole

3115
01:52:48,870 --> 01:52:46,800
machinery gets degraded i've i've

3116
01:52:51,109 --> 01:52:48,880
parameterized all this based on

3117
01:52:52,870 --> 01:52:51,119
work of 15 other

3118
01:52:54,149 --> 01:52:52,880
groups i've you have done amazing

3119
01:52:56,709 --> 01:52:54,159
experiments

3120
01:53:00,149 --> 01:52:56,719
and um what i'm able to do is i'm able

3121
01:53:02,709 --> 01:53:00,159
to vary the light level and allow the

3122
01:53:04,790 --> 01:53:02,719
amount of antenna to vary and create a

3123
01:53:07,270 --> 01:53:04,800
numerical solution for the optimal

3124
01:53:09,669 --> 01:53:07,280
chlorophototroph and the optimal retinal

3125
01:53:12,470 --> 01:53:09,679
phototroph for a given light intensity

3126
01:53:13,910 --> 01:53:12,480
which is sort of an ecological sub-niche

3127
01:53:16,149 --> 01:53:13,920
when i do that

3128
01:53:18,629 --> 01:53:16,159
this is what i get this is light

3129
01:53:21,109 --> 01:53:18,639
intensity from super low all the way up

3130
01:53:23,430 --> 01:53:21,119
to direct sunlight at the equator

3131
01:53:26,390 --> 01:53:23,440
and this is the efficiency per unit

3132
01:53:29,510 --> 01:53:26,400
light of the two systems and efficiency

3133
01:53:31,910 --> 01:53:29,520
per unit protein of the two systems so

3134
01:53:33,430 --> 01:53:31,920
at low light once again the chlorophyll

3135
01:53:36,229 --> 01:53:33,440
wins hands down and highlight the

3136
01:53:37,910 --> 01:53:36,239
retinal winds uh hands down

3137
01:53:40,629 --> 01:53:37,920
and when i actually look at their

3138
01:53:43,510 --> 01:53:40,639

compositions um this is the amount of

3139
01:53:46,229 --> 01:53:43,520
antenna associated with each system

3140
01:53:48,709 --> 01:53:46,239
um at their crossover point um this

3141
01:53:51,189 --> 01:53:48,719
amount of antenna is within 30 percent

3142
01:53:52,790 --> 01:53:51,199
of the smallest known antenna of actual

3143
01:53:56,390 --> 01:53:52,800
chlorophyll terrific system so i think

3144
01:53:59,030 --> 01:53:56,400
i'm on to something and the uh

3145
01:54:01,990 --> 01:53:59,040
expected largest antenna for the um

3146
01:54:04,629 --> 01:54:02,000
retinol it's smaller than the smallest

3147
01:54:06,310 --> 01:54:04,639
antenna that ever actually exists and so

3148
01:54:08,709 --> 01:54:06,320
the fact that there's no

3149
01:54:10,950 --> 01:54:08,719
retinal systems with an antenna other

3150
01:54:13,189 --> 01:54:10,960
than just sort of a extra dye molecule

3151
01:54:15,270 --> 01:54:13,199
shoved into a gap in the mall in the in

3152
01:54:16,709 --> 01:54:15,280
the protein i think again i think i'm on

3153
01:54:19,189 --> 01:54:16,719
to something i'm reproducing what

3154
01:54:21,030 --> 01:54:19,199
actually is seen

3155
01:54:22,550 --> 01:54:21,040
and like once again i can i can

3156
01:54:25,030 --> 01:54:22,560
parameterize this however i want this is

3157
01:54:27,270 --> 01:54:25,040
sort of the the advantage that each of

3158
01:54:29,270 --> 01:54:27,280
them that each system has at different

3159
01:54:30,709 --> 01:54:29,280
light levels so once again

3160
01:54:32,870 --> 01:54:30,719
the chlorophyll

3161
01:54:35,589 --> 01:54:32,880
is efficient per unit resource at low

3162
01:54:38,390 --> 01:54:35,599
resource availability the

3163
01:54:41,910 --> 01:54:38,400

retinal is efficient per unit uh

3164
01:54:43,669 --> 01:54:41,920
investment at high light availability

3165
01:54:46,870 --> 01:54:43,679
and if you want to sort of turn this

3166
01:54:48,470 --> 01:54:46,880
into a summary this is

3167
01:54:50,390 --> 01:54:48,480
instead of the axis of light you have

3168
01:54:52,709 --> 01:54:50,400
efficiency per unit protein

3169
01:54:54,790 --> 01:54:52,719
versus efficiency per unit light and

3170
01:54:56,709 --> 01:54:54,800
these are the two systems and together

3171
01:54:58,070 --> 01:54:56,719
this defines what you call a pareto

3172
01:55:01,030 --> 01:54:58,080
front so

3173
01:55:03,109 --> 01:55:01,040
this altogether is the trade-off along

3174
01:55:05,750 --> 01:55:03,119
which you have to move as something that

3175
01:55:07,350 --> 01:55:05,760
can compete in the world today you start

3176
01:55:09,189 --> 01:55:07,360
out if you start off down here you're

3177
01:55:11,270 --> 01:55:09,199
not going to be able to do well somebody

3178
01:55:13,910 --> 01:55:11,280
is going to be better than you if you're

3179
01:55:15,430 --> 01:55:13,920
on this line you can move along this

3180
01:55:17,350 --> 01:55:15,440
line but the but the fundamental

3181
01:55:19,189 --> 01:55:17,360
structure keeps you from getting better

3182
01:55:20,870 --> 01:55:19,199
on all axes in order to get better on

3183
01:55:22,629 --> 01:55:20,880
one axis you need to get worse on the

3184
01:55:24,390 --> 01:55:22,639
other

3185
01:55:26,629 --> 01:55:24,400
so

3186
01:55:28,709 --> 01:55:26,639
this efficiency per protein versus

3187
01:55:31,589 --> 01:55:28,719
efficiency per resource trade-off is all

3188
01:55:33,350 --> 01:55:31,599

over microbial ecology not just this

3189
01:55:36,149 --> 01:55:33,360
this is exactly the trade-off that's in

3190
01:55:37,510 --> 01:55:36,159
respiration and fermentation this is um

3191
01:55:40,470 --> 01:55:37,520
this diagram

3192
01:55:43,270 --> 01:55:40,480
in fermentation you're throwing lots of

3193
01:55:45,589 --> 01:55:43,280
uh substrate in the trash

3194
01:55:47,589 --> 01:55:45,599
and you get a certain amount of atp

3195
01:55:48,950 --> 01:55:47,599
respiration you use less substrate for

3196
01:55:50,629 --> 01:55:48,960
the same atp but you need a lot more

3197
01:55:53,350 --> 01:55:50,639
protein there's different forms of

3198
01:55:54,950 --> 01:55:53,360
glycolysis that um have exactly the same

3199
01:55:56,149 --> 01:55:54,960
trade-off that you find in arabs versus

3200
01:55:58,149 --> 01:55:56,159
anaerobes

3201
01:56:01,030 --> 01:55:58,159
and when you are maximizing return on a

3202
01:56:04,470 --> 01:56:01,040
small investment this

3203
01:56:06,550 --> 01:56:04,480
maximizes your growth rate

3204
01:56:07,830 --> 01:56:06,560
in rich resources or your flexibility

3205
01:56:09,669 --> 01:56:07,840
because you can have more kinds of

3206
01:56:12,229 --> 01:56:09,679
machinery and if you're maximizing

3207
01:56:14,390 --> 01:56:12,239
return on a resource that maximizes your

3208
01:56:16,070 --> 01:56:14,400
yield on a rare resource or your ability

3209
01:56:17,589 --> 01:56:16,080
to be a specialist in some kind of

3210
01:56:18,470 --> 01:56:17,599
narrow niche

3211
01:56:19,990 --> 01:56:18,480
so

3212
01:56:22,229 --> 01:56:20,000
what does this say

3213
01:56:24,629 --> 01:56:22,239

um about this about this major

3214
01:56:26,229 --> 01:56:24,639
innovation there's extremely precise

3215
01:56:27,510 --> 01:56:26,239
niche partitioning between these two

3216
01:56:29,430 --> 01:56:27,520
phototrophs

3217
01:56:31,350 --> 01:56:29,440
they neatly divide the phototrophic

3218
01:56:33,510 --> 01:56:31,360
niche with one being efficient in terms

3219
01:56:35,109 --> 01:56:33,520
of investment and one being efficient in

3220
01:56:37,189 --> 01:56:35,119
terms of resource

3221
01:56:39,189 --> 01:56:37,199
um and there's other aspects which i'm

3222
01:56:40,629 --> 01:56:39,199
not getting into here but every way you

3223
01:56:42,310 --> 01:56:40,639
look at them they're actually really

3224
01:56:44,310 --> 01:56:42,320
complementary in terms of what makes

3225
01:56:46,149 --> 01:56:44,320
them up their ability to horizontally

3226
01:56:49,270 --> 01:56:46,159
transfer even the wavelengths of light

3227
01:56:51,109 --> 01:56:49,280
they use it's it's it's eerie

3228
01:56:53,270 --> 01:56:51,119
um and i think it's unlikely that these

3229
01:56:55,030 --> 01:56:53,280
would be dividing the niche so

3230
01:56:57,270 --> 01:56:55,040
precisely if their properties were

3231
01:56:58,470 --> 01:56:57,280
random i don't think they are

3232
01:57:00,470 --> 01:56:58,480
and this suggests that there's

3233
01:57:03,030 --> 01:57:00,480
ecological interactions in their past

3234
01:57:04,550 --> 01:57:03,040
causing evolutionary priority effects

3235
01:57:05,350 --> 01:57:04,560
and that's where

3236
01:57:07,589 --> 01:57:05,360
um

3237
01:57:09,669 --> 01:57:07,599
something evolves into a new niche it

3238
01:57:12,709 --> 01:57:09,679

spreads and fills it it gets good at

3239
01:57:14,790 --> 01:57:12,719
that niche and prevents new upstarts

3240
01:57:17,109 --> 01:57:14,800
from surviving in that niche because

3241
01:57:19,750 --> 01:57:17,119
they are going to be very bad compared

3242
01:57:21,669 --> 01:57:19,760
to it and i think each mode of photo

3243
01:57:24,470 --> 01:57:21,679
trophy has been suppressing the

3244
01:57:26,229 --> 01:57:24,480
evolution of things too like themselves

3245
01:57:27,750 --> 01:57:26,239
now let's look at that in just a little

3246
01:57:28,790 --> 01:57:27,760
more detail because the story gets

3247
01:57:29,830 --> 01:57:28,800
interesting

3248
01:57:33,430 --> 01:57:29,840
um

3249
01:57:35,830 --> 01:57:33,440
this is sort of a diagram of the process

3250
01:57:37,350 --> 01:57:35,840
of evolution based on that trade-off

3251
01:57:39,109 --> 01:57:37,360
that we saw before

3252
01:57:42,390 --> 01:57:39,119
either one of these is going to start

3253
01:57:43,830 --> 01:57:42,400
off bad on both in both respects and

3254
01:57:46,950 --> 01:57:43,840
it's going to evolve through some free

3255
01:57:49,510 --> 01:57:46,960
lunches getting better in terms of

3256
01:57:51,510 --> 01:57:49,520
resource and investment until it hits

3257
01:57:54,229 --> 01:57:51,520
the physical limit and then it's forced

3258
01:57:55,189 --> 01:57:54,239
to trade off along this front the thing

3259
01:57:57,910 --> 01:57:55,199
is

3260
01:57:59,589 --> 01:57:57,920
both of these have a full trade-off

3261
01:58:01,350 --> 01:57:59,599
front and so

3262
01:58:03,990 --> 01:58:01,360
why are there two you want you might

3263
01:58:07,030 --> 01:58:04,000

expect that whoever came first

3264
01:58:08,950 --> 01:58:07,040
would have just filled this entire front

3265
01:58:12,470 --> 01:58:08,960
and prevented the evolution of

3266
01:58:14,709 --> 01:58:12,480
everything strictly inferior to it and

3267
01:58:15,910 --> 01:58:14,719
it turns out that

3268
01:58:17,830 --> 01:58:15,920
there is something that a

3269
01:58:19,270 --> 01:58:17,840
chlorophytotroph can do that a retinal

3270
01:58:21,510 --> 01:58:19,280
phototroph can't

3271
01:58:23,030 --> 01:58:21,520
no retinal phototroph can build biomass

3272
01:58:25,270 --> 01:58:23,040
using light it just doesn't pump the

3273
01:58:28,149 --> 01:58:25,280
membrane up to a high enough voltage to

3274
01:58:29,350 --> 01:58:28,159
run to run redox reactions in reverse

3275
01:58:32,470 --> 01:58:29,360
so

3276
01:58:34,149 --> 01:58:32,480
even a very bad chlorophototroph can

3277
01:58:35,510 --> 01:58:34,159
make a reducing agent that can build

3278
01:58:36,629 --> 01:58:35,520
biomass

3279
01:58:38,070 --> 01:58:36,639
so

3280
01:58:40,709 --> 01:58:38,080
what this says to me is that i think

3281
01:58:42,390 --> 01:58:40,719
it's likely that retinal phototrophy had

3282
01:58:43,669 --> 01:58:42,400
to have come first

3283
01:58:46,149 --> 01:58:43,679
because

3284
01:58:48,709 --> 01:58:46,159
um if chlorophyll trophy came first now

3285
01:58:50,629 --> 01:58:48,719
the first awful retinal phototroph would

3286
01:58:52,310 --> 01:58:50,639
have been worse than chlorophototrophs

3287
01:58:53,750 --> 01:58:52,320
on all axes

3288
01:58:56,149 --> 01:58:53,760

whereas

3289
01:58:58,310 --> 01:58:56,159
if the retinal phototroph came first the

3290
01:59:00,070 --> 01:58:58,320
first chlorophototroph had one trick it

3291
01:59:01,109 --> 01:59:00,080
could do and it was able to evolve and

3292
01:59:03,669 --> 01:59:01,119
then

3293
01:59:05,430 --> 01:59:03,679
knock off this part of the trade-off in

3294
01:59:07,350 --> 01:59:05,440
this um energy

3295
01:59:08,470 --> 01:59:07,360
space

3296
01:59:10,310 --> 01:59:08,480
so

3297
01:59:12,070 --> 01:59:10,320
in summary i think this is i think this

3298
01:59:13,669 --> 01:59:12,080
is what has been happening across the

3299
01:59:15,910 --> 01:59:13,679
history of life on earth this is sort of

3300
01:59:18,550 --> 01:59:15,920
the space of ecological niches you

3301
01:59:20,790 --> 01:59:18,560
invent a bad a bad retinal phototroph it

3302
01:59:22,550 --> 01:59:20,800
gets better it fills a bunch of niches

3303
01:59:24,550 --> 01:59:22,560
then you invent a chlorophytotroph it

3304
01:59:26,629 --> 01:59:24,560
gets better it fills a bunch of niches

3305
01:59:28,870 --> 01:59:26,639
it kicks retinal phototrophy out of some

3306
01:59:30,870 --> 01:59:28,880
of those niches but not all because

3307
01:59:32,310 --> 01:59:30,880
they're sufficiently different

3308
01:59:34,470 --> 01:59:32,320
and both of them have been suppressing

3309
01:59:36,629 --> 01:59:34,480
the evolution of things to like

3310
01:59:38,629 --> 01:59:36,639
themselves ever since

3311
01:59:41,350 --> 01:59:38,639
and you can imagine very different

3312
01:59:43,629 --> 01:59:41,360
circumstances we see something like this

3313
01:59:45,750 --> 01:59:43,639

on the left with animals and

3314
01:59:47,430 --> 01:59:45,760
multicellularity just more and more

3315
01:59:48,950 --> 01:59:47,440
multi-cells keep popping up over and

3316
01:59:50,229 --> 01:59:48,960
over and over again they don't seem to

3317
01:59:51,910 --> 01:59:50,239
interfere with each other or step on

3318
01:59:53,430 --> 01:59:51,920
each other's toes

3319
01:59:55,189 --> 01:59:53,440
you could also imagine a circumstance

3320
01:59:57,990 --> 01:59:55,199
though where something like this happens

3321
02:00:00,310 --> 01:59:58,000
but the niche space just wasn't um

3322
02:00:02,470 --> 02:00:00,320
complex enough for there to be space for

3323
02:00:05,510 --> 02:00:02,480
more than one and somebody fills the

3324
02:00:07,270 --> 02:00:05,520
entire niche and completely suppresses

3325
02:00:08,070 --> 02:00:07,280
everyone for all time

3326
02:00:10,629 --> 02:00:08,080
so

3327
02:00:13,350 --> 02:00:10,639
conclusions i think photo trophy is easy

3328
02:00:15,750 --> 02:00:13,360
to evolve it originated independently

3329
02:00:17,430 --> 02:00:15,760
twice from co-opted non-phototrophic

3330
02:00:18,470 --> 02:00:17,440
systems you can see what some of the

3331
02:00:21,030 --> 02:00:18,480
things that probably came from in the

3332
02:00:22,550 --> 02:00:21,040
case of chlorophototrophy i think this

3333
02:00:23,990 --> 02:00:22,560
should be very early in earth's history

3334
02:00:25,350 --> 02:00:24,000
and be ubiquitous in any other

3335
02:00:27,510 --> 02:00:25,360
biospheres

3336
02:00:29,350 --> 02:00:27,520
i think that this whole dual singularity

3337
02:00:32,550 --> 02:00:29,360
aspect suggests that major innovations

3338
02:00:35,030 --> 02:00:32,560

can rapidly become unbeatable incumbents

3339
02:00:36,229 --> 02:00:35,040
that leave unrefined upstarts unable to

3340
02:00:37,910 --> 02:00:36,239
compete

3341
02:00:39,830 --> 02:00:37,920
and i think right now a photo trophy

3342
02:00:42,390 --> 02:00:39,840
likely evolved first

3343
02:00:43,270 --> 02:00:42,400
for reasons that i said before

3344
02:00:45,350 --> 02:00:43,280
and

3345
02:00:47,270 --> 02:00:45,360
i think other evolutionary singularities

3346
02:00:48,950 --> 02:00:47,280
might be singular due to these priority

3347
02:00:50,790 --> 02:00:48,960
effects rather than difficulty or

3348
02:00:53,430 --> 02:00:50,800
contingency and i think we need to look

3349
02:00:55,990 --> 02:00:53,440
carefully at the niche structures that

3350
02:00:58,229 --> 02:00:56,000
can cause this phenomenon sometimes but

3351
02:00:59,750 --> 02:00:58,239
not other times and i think

3352
02:01:02,149 --> 02:00:59,760
eukaryogenesis

3353
02:01:05,589 --> 02:01:02,159
or genetic code origin of life are all

3354
02:01:07,910 --> 02:01:05,599
prime candidates um i have thoughts on

3355
02:01:09,910 --> 02:01:07,920
how there might actually be little bits

3356
02:01:11,350 --> 02:01:09,920
of evidence of other things approaching

3357
02:01:12,950 --> 02:01:11,360
the complex cell architecture of

3358
02:01:15,350 --> 02:01:12,960
eukaryogenesis which i would love to

3359
02:01:17,430 --> 02:01:15,360
talk to people later and and i have

3360
02:01:19,350 --> 02:01:17,440
ideas so

3361
02:01:21,030 --> 02:01:19,360
uh and this has even inspired some lab

3362
02:01:22,790 --> 02:01:21,040
work i'm now putting rhodopsins into

3363
02:01:24,709 --> 02:01:22,800

yeast and studying how it's affecting

3364
02:01:26,149 --> 02:01:24,719
the evolution of their multicellularity

3365
02:01:27,589 --> 02:01:26,159
turns out there's there's interesting

3366
02:01:29,109 --> 02:01:27,599
experimental stuff to be done with this

3367
02:01:30,390 --> 02:01:29,119
too so

3368
02:01:33,270 --> 02:01:30,400
uh let's thank you all for your

3369
02:01:34,950 --> 02:01:33,280
attention thank uh will ratcliffe for

3370
02:01:36,390 --> 02:01:34,960
letting me go off on these tangents

3371
02:01:38,870 --> 02:01:36,400
ozone for

3372
02:01:40,790 --> 02:01:38,880
constantly inspiring me in the lab and

3373
02:01:42,390 --> 02:01:40,800
autumn for uh

3374
02:01:43,910 --> 02:01:42,400
doing some of these cool experiments

3375
02:01:47,120 --> 02:01:43,920
with red dobson that i've just started

3376
02:01:52,310 --> 02:01:47,130
recently so any questions

3377
02:01:57,589 --> 02:01:54,390
thanks tony that was really exciting and

3378
02:02:00,470 --> 02:01:57,599
thank you beautiful talk i have um a

3379
02:02:01,910 --> 02:02:00,480
question about the retinol nala troves

3380
02:02:04,550 --> 02:02:01,920
coming first

3381
02:02:07,270 --> 02:02:04,560
don't you need chlorophyll

3382
02:02:10,709 --> 02:02:07,280
first in order to make oxygen because

3383
02:02:14,070 --> 02:02:10,719
retinol requires oxygen to be made

3384
02:02:15,270 --> 02:02:14,080
retinal does need oxygen to be made um

3385
02:02:16,709 --> 02:02:15,280
thing is

3386
02:02:19,189 --> 02:02:16,719
i don't think that necessarily tells you

3387
02:02:21,510 --> 02:02:19,199
anything because

3388
02:02:25,750 --> 02:02:21,520

you also have chlorophyll getting made

3389
02:02:27,510 --> 02:02:25,760
with oxygen in a lot of organisms today

3390
02:02:31,589 --> 02:02:27,520
and secondly

3391
02:02:34,629 --> 02:02:31,599
today in this oxygen soaked world

3392
02:02:37,350 --> 02:02:34,639
every um the the retinal organisms they

3393
02:02:39,510 --> 02:02:37,360
do a lot better in bright light is there

3394
02:02:41,830 --> 02:02:39,520
a place on earth that has bright light

3395
02:02:57,669 --> 02:02:41,840
that doesn't have oxygen today

3396
02:03:02,790 --> 02:03:00,629
yeah but once but yeah but and so if the

3397
02:03:04,709 --> 02:03:02,800
other thing is though the the a pathway

3398
02:03:06,950 --> 02:03:04,719
that uses oxygen to make this is going

3399
02:03:08,629 --> 02:03:06,960
to be a lot shorter and simpler than a

3400
02:03:10,790 --> 02:03:08,639
pathway that doesn't

3401
02:03:13,270 --> 02:03:10,800
so if you consider the synthesis

3402
02:03:14,390 --> 02:03:13,280
machinery for the pigment as part of the

3403
02:03:16,550 --> 02:03:14,400
machinery

3404
02:03:18,950 --> 02:03:16,560
you also get a major advantage if you

3405
02:03:20,550 --> 02:03:18,960
can cut down on that synthesis

3406
02:03:24,149 --> 02:03:20,560
machinery so

3407
02:03:26,550 --> 02:03:24,159
um but on the and on and for point three

3408
02:03:28,870 --> 02:03:26,560
i don't know that anyone would recognize

3409
02:03:31,270 --> 02:03:28,880
a non-oxygen non-oxygen-using pathway to

3410
02:03:33,030 --> 02:03:31,280
make that if they saw it

3411
02:03:35,510 --> 02:03:33,040
um like there's like they've

3412
02:03:37,669 --> 02:03:35,520
characterized the oxygen using pathway

3413
02:03:38,870 --> 02:03:37,679

you might just see oh this thing has a

3414
02:03:41,030 --> 02:03:38,880
rhodopsin but it doesn't have a

3415
02:03:42,950 --> 02:03:41,040
synthesis pathway like like are we are

3416
02:03:44,870 --> 02:03:42,960
we sure that we have not actually seen

3417
02:03:48,470 --> 02:03:44,880
that so between all these things i'm not

3418
02:03:54,390 --> 02:03:51,350
so tony it seems like the the really

3419
02:03:57,510 --> 02:03:54,400
important aspect of determining

3420
02:03:59,109 --> 02:03:57,520
how many um origins of a major

3421
02:04:02,229 --> 02:03:59,119
transition

3422
02:04:04,149 --> 02:04:02,239
is its ability to spread and fill an

3423
02:04:07,669 --> 02:04:04,159
ecological niche

3424
02:04:09,270 --> 02:04:07,679
is there any way that you can

3425
02:04:12,069 --> 02:04:09,280
um

3426
02:04:14,629 --> 02:04:12,079
sort of suss that out how how quickly

3427
02:04:16,709 --> 02:04:14,639
can it spread or did it spread that

3428
02:04:18,629 --> 02:04:16,719
would allow you to sort of test this

3429
02:04:20,629 --> 02:04:18,639
hypothesis

3430
02:04:23,030 --> 02:04:20,639
so like is there a way to look back into

3431
02:04:25,030 --> 02:04:23,040
the history of a particular major

3432
02:04:26,709 --> 02:04:25,040
innovation and see how see how quickly

3433
02:04:29,910 --> 02:04:26,719
it's well in particular this one is

3434
02:04:33,189 --> 02:04:29,920
there any way to to determine from

3435
02:04:35,030 --> 02:04:33,199
existing you know geological evidence or

3436
02:04:36,790 --> 02:04:35,040
um

3437
02:04:40,550 --> 02:04:36,800
genomic evidence

3438
02:04:42,149 --> 02:04:40,560

how quickly it did spread in its

3439
02:04:44,709 --> 02:04:42,159
ecological niche

3440
02:04:47,189 --> 02:04:44,719
let's see uh

3441
02:04:50,069 --> 02:04:47,199
you might you might make an argument

3442
02:04:52,470 --> 02:04:50,079
about like stem lengths about like with

3443
02:04:53,430 --> 02:04:52,480
like stem groups and crown groups like

3444
02:04:56,149 --> 02:04:53,440
um

3445
02:04:57,669 --> 02:04:56,159
there's the there's whether there's

3446
02:04:59,430 --> 02:04:57,679
there's there's the crown group which is

3447
02:05:01,189 --> 02:04:59,440
the everything that's around today and

3448
02:05:02,790 --> 02:05:01,199
its common ancestor and then there's the

3449
02:05:04,390 --> 02:05:02,800
stem where it was still doing something

3450
02:05:05,510 --> 02:05:04,400
like today but then only one thing

3451
02:05:07,030 --> 02:05:05,520
appears because none of these

3452
02:05:08,790 --> 02:05:07,040
innovations are a single step there's

3453
02:05:10,790 --> 02:05:08,800
lots and lots of steps

3454
02:05:11,990 --> 02:05:10,800
and presumably you're on the stem as

3455
02:05:13,350 --> 02:05:12,000
you're approaching the trade-off and

3456
02:05:15,350 --> 02:05:13,360
then once you're on the trade-off you

3457
02:05:16,709 --> 02:05:15,360
start having diversity that remains

3458
02:05:17,510 --> 02:05:16,719
around today

3459
02:05:19,109 --> 02:05:17,520
so

3460
02:05:20,870 --> 02:05:19,119
you could make i suppose you might be

3461
02:05:23,510 --> 02:05:20,880
able to make an argument about like how

3462
02:05:24,870 --> 02:05:23,520
big are those stems what what how much

3463
02:05:28,069 --> 02:05:24,880

had to happen

3464
02:05:30,790 --> 02:05:28,079
along that uh along that path and

3465
02:05:32,950 --> 02:05:30,800
and how and how quickly um did it have

3466
02:05:34,310 --> 02:05:32,960
to go there so like you uh that's more

3467
02:05:37,510 --> 02:05:34,320
about the of the speed with which you

3468
02:05:39,510 --> 02:05:37,520
approach it but uh but i think i have

3469
02:05:40,870 --> 02:05:39,520
i've i've been i've thought about like

3470
02:05:42,229 --> 02:05:40,880
major innovations like like

3471
02:05:44,629 --> 02:05:42,239
eukaryogenesis where you have this

3472
02:05:46,390 --> 02:05:44,639
enormously long stem with so many things

3473
02:05:48,310 --> 02:05:46,400
happening along it and lots of people

3474
02:05:50,629 --> 02:05:48,320
like to say that had to take a long time

3475
02:05:51,750 --> 02:05:50,639
i'm not so sure evolution can happen

3476
02:05:53,589 --> 02:05:51,760
fast

3477
02:05:56,069 --> 02:05:53,599
um especially when there's major

3478
02:05:58,629 --> 02:05:56,079
selective advantages but um

3479
02:06:00,149 --> 02:05:58,639
yeah i think i think that's that's how i

3480
02:06:02,390 --> 02:06:00,159
would think about approaching it look

3481
02:06:04,069 --> 02:06:02,400
looking at the stems and when the stems

3482
02:06:08,390 --> 02:06:04,079
had to happen and what had to happen in

3483
02:06:08,400 --> 02:06:11,830
great and then one last question

3484
02:06:14,790 --> 02:06:13,990
thanks so much i i had a question about

3485
02:06:18,629 --> 02:06:14,800
the

3486
02:06:20,790 --> 02:06:18,639
um

3487
02:06:22,470 --> 02:06:20,800
system that it seems like it had a lot

3488
02:06:24,310 --> 02:06:22,480

of parts and that early on it probably

3489
02:06:26,229 --> 02:06:24,320
had fewer parts and did those parts look

3490
02:06:27,510 --> 02:06:26,239
like the rhodopsin parts at least in

3491
02:06:29,030 --> 02:06:27,520
cartoon form

3492
02:06:31,910 --> 02:06:29,040
they don't look like they're adopting

3493
02:06:35,030 --> 02:06:31,920
parts at all um the rhodopsin is this

3494
02:06:37,109 --> 02:06:35,040
little small transmembrane protein that

3495
02:06:39,510 --> 02:06:37,119
just literally mechanically is pushing

3496
02:06:42,709 --> 02:06:39,520
protons around as the pigment changes

3497
02:06:44,790 --> 02:06:42,719
shape in response to uh light liter

3498
02:06:46,069 --> 02:06:44,800
literally a double bond switches from

3499
02:06:48,709 --> 02:06:46,079
cyst to trans

3500
02:06:51,189 --> 02:06:48,719
in response to absorbing a photon the

3501
02:06:52,629 --> 02:06:51,199
chlorophyll stuff it's it's it's part of

3502
02:06:54,790 --> 02:06:52,639
an electron transport chain you are

3503
02:06:56,149 --> 02:06:54,800
boosting electrons to different redox

3504
02:06:58,870 --> 02:06:56,159
levels in response to light and then

3505
02:07:00,790 --> 02:06:58,880
they're tunneling around and so um but

3506
02:07:02,790 --> 02:07:00,800
do you think the antenna came first

3507
02:07:04,870 --> 02:07:02,800
uh for the motor i think what do you

3508
02:07:06,870 --> 02:07:04,880
mean well you had the different parts

3509
02:07:08,149 --> 02:07:06,880
the components in cartoon form you had

3510
02:07:09,830 --> 02:07:08,159
the antenna

3511
02:07:12,470 --> 02:07:09,840
and you had the motor and then the

3512
02:07:13,669 --> 02:07:12,480
adoption one looks so so so the

3513
02:07:16,470 --> 02:07:13,679

interesting thing when you think about

3514
02:07:19,350 --> 02:07:16,480
their their pre-dependencies

3515
02:07:23,189 --> 02:07:19,360
for rhodopsin all that you need is

3516
02:07:25,510 --> 02:07:23,199
uh a membrane with uh with a uh with a

3517
02:07:27,669 --> 02:07:25,520
with a proton gradient that is used to

3518
02:07:30,550 --> 02:07:27,679
do work like it is it is an advocate it

3519
02:07:32,870 --> 02:07:30,560
is an advantage in that circumstance

3520
02:07:35,270 --> 02:07:32,880
for chlorophyll you need

3521
02:07:37,669 --> 02:07:35,280
reed you need um electron transport

3522
02:07:39,270 --> 02:07:37,679
chains basically and i would i

3523
02:07:41,350 --> 02:07:39,280
you you can also make the argument

3524
02:07:44,229 --> 02:07:41,360
that's more dependencies

3525
02:07:45,750 --> 02:07:44,239
for for the one to work than the other

3526
02:07:50,709 --> 02:07:45,760
does that make sense

3527
02:08:06,069 --> 02:07:52,830
great well thank you

3528
02:08:11,030 --> 02:08:07,750
and now we have the honor of turning

3529
02:08:15,000 --> 02:08:11,040
this over to professor jen glass and

3530
02:08:34,950 --> 02:08:15,010
uh professor francis rivera hernandez

3531
02:08:39,430 --> 02:08:37,669
okay welcome to our

3532
02:08:40,940 --> 02:08:39,440
first

3533
02:08:43,510 --> 02:08:40,950
ever in person

3534
02:08:46,510 --> 02:08:43,520
[Laughter]

3535
02:08:50,310 --> 02:08:46,520
[Applause]

3536
02:08:52,310 --> 02:08:50,320
astrobiology certificate ceremony so if

3537
02:08:53,750 --> 02:08:52,320
everybody that's getting a certificate

3538
02:08:56,310 --> 02:08:53,760

can come on

3539
02:08:58,790 --> 02:08:56,320
well i'll call you up we'll call you up

3540
02:09:00,390 --> 02:08:58,800
so um maybe somebody can just flip

3541
02:09:03,189 --> 02:09:00,400
through the slides that'd be great

3542
02:09:06,790 --> 02:09:03,199
christina thank you

3543
02:09:09,030 --> 02:09:06,800
so yes uh so we're just gonna yeah go

3544
02:09:12,390 --> 02:09:09,040
through the slides and alternate okay so

3545
02:09:14,400 --> 02:09:12,400
our first recipient is alex sessa

3546
02:09:23,669 --> 02:09:14,410
congratulations

3547
02:09:28,340 --> 02:09:25,990
yeah our second recipient is riley

3548
02:09:41,850 --> 02:09:28,350
brennan

3549
02:09:41,860 --> 02:09:45,950
[Music]

3550
02:09:49,430 --> 02:09:47,910
congratulations

3551
02:09:51,030 --> 02:09:49,440
yes and you should stay up here we're

3552
02:09:54,149 --> 02:09:51,040
going to get a picture we'll do like an

3553
02:09:55,830 --> 02:09:54,159
elbow bump from now

3554
02:10:05,750 --> 02:09:55,840
hey

3555
02:10:05,760 --> 02:10:10,229
congratulations

3556
02:10:13,630 --> 02:10:12,470
and our next recipient is justin

3557
02:10:18,790 --> 02:10:13,640
lawrence

3558
02:10:22,260 --> 02:10:18,800
[Applause]

3559
02:10:26,990 --> 02:10:22,270
next up maria granada

3560
02:10:28,709 --> 02:10:27,000
[Applause]

3561
02:10:30,229 --> 02:10:28,719
[Music]

3562
02:10:33,589 --> 02:10:30,239
congratulations

3563
02:10:35,270 --> 02:10:33,599

and um i think oscar is in the air force

3564
02:10:38,640 --> 02:10:35,280
right now so he's probably not here but

3565
02:10:40,310 --> 02:10:38,650
oscar klempe congratulations

3566
02:10:42,120 --> 02:10:40,320
[Applause]

3567
02:10:48,390 --> 02:10:42,130
next up tyler roach

3568
02:10:53,589 --> 02:10:51,189
[Music]

3569
02:10:56,069 --> 02:10:53,599
and next up is katie

3570
02:10:57,830 --> 02:10:56,079
cube who's i think is online

3571
02:11:02,550 --> 02:10:57,840
congratulations

3572
02:11:12,550 --> 02:11:05,540
next up rebecca gloop butler

3573
02:11:18,750 --> 02:11:15,510
and next up is kavita

3574
02:11:24,629 --> 02:11:21,669
[Applause]

3575
02:11:26,550 --> 02:11:24,639
all right next up chase shivers

3576
02:11:27,630 --> 02:11:26,560
which i saw before i think he's around

3577
02:11:30,069 --> 02:11:27,640
but not he's not back

3578
02:11:33,189 --> 02:11:30,079
[Applause]

3579
02:11:36,830 --> 02:11:34,550
okay

3580
02:11:39,850 --> 02:11:36,840
and next up is

3581
02:11:44,550 --> 02:11:39,860
jordan jordan mccain

3582
02:11:44,560 --> 02:11:48,709
and then taylor plattner

3583
02:11:48,719 --> 02:11:53,990
go mars

3584
02:11:57,910 --> 02:11:55,430
congratulations

3585
02:12:00,629 --> 02:11:57,920
i need to get a shirt for you i have one

3586
02:12:13,300 --> 02:12:00,639
i just i left it out oh we had them in

3587
02:12:19,160 --> 02:12:16,229
[Applause]

3588
02:12:27,430 --> 02:12:19,170

hey

3589
02:12:32,390 --> 02:12:30,750
yeah next up elizabeth spears

3590
02:12:35,669 --> 02:12:32,400
[Applause]

3591
02:12:40,790 --> 02:12:38,229
online she's online and

3592
02:12:43,390 --> 02:12:40,800
last but not least marissa

3593
02:12:46,500 --> 02:12:43,400
congratulations smear says the money

3594
02:12:48,940 --> 02:12:46,510
[Applause]

3595
02:12:57,669 --> 02:12:48,950
[Music]

3596
02:12:57,679 --> 02:13:04,740
maybe we could do everybody like

3597
02:13:04,750 --> 02:13:09,430
[Applause]

3598
02:13:12,310 --> 02:13:11,030
maybe a couple people

3599
02:13:20,510 --> 02:13:12,320
bunch of

3600
02:13:20,520 --> 02:13:25,589
[Music]

3601
02:13:25,599 --> 02:13:30,350
is

3602
02:13:30,360 --> 02:13:33,870
[Music]

3603
02:13:33,880 --> 02:13:39,370
[Laughter]

3604
02:13:54,310 --> 02:13:42,229
[Music]

3605
02:13:57,510 --> 02:13:55,270
hey

3606
02:14:06,050 --> 02:13:57,520
thank you